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RESPIRATORY CARE

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36TH YEAR—ESTABLISHED 1956

1991 OPEN FORUM Abstracts

- Sweeter Is Not Necessarily Better
- Comparison of Two Methods of Preoxygenation during ET Suctioning
- Influence of I.V. Dextrose on Carbohydrate Intake of Critically Ill Patients on Nutritional Support
- Manual Ventilation during MRI
- Acute Effects of Smoke Injury to Lung Parenchyma
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To Thwart the Tobacco Companies: It's Every Physician's Responsibility (editorial)—Sullivan LW. JAMA 1991;266:2131. (Pertains to Samuels & Glantz paper abstracted below.)

Sodium Bicarbonate in CPR (editorial)—Weisfeldt ML. JAMA 1991;266:2129. (Pertains to Kette et al paper abstracted on the following pages.)

The Polities of Local Tobacco Control—B Samuels, SA Glantz. JAMA 1991;266:2110.

Until the nonsmokers' rights movement, tobacco control activity was at the federal or state levels, which is where the tobacco industry dominates. Since the appearance of the nonsmokers' rights movement, progress in tobacco control has occurred primarily at the local level. In response to the success of this movement, the tobacco industry has developed "smokers' rights" groups and other tactics to fight local legislation. Several recent local campaigns in California illustrate the tactics. Tobacco control forces follow many paths, from sitting on the sidelines to making a serious commitment to smoking control legislation. Despite the tobacco industry's superior financial resources, the outcome of proposed local tobacco control legislation appears to depend on how seriously the health advocates mobilize in support of the local legislation. When the health community makes a serious commitment of time and resources, it wins. When it fails to make such a commitment, the tobacco industry prevails, more by default than by its superior financial resources.

Psychological Stress and Susceptibility to the Common Cold—S Cohen, DAJ Tyrrell, AP Smith. N Engl J Med 1991;325:606.

BACKGROUND: It is not known whether psychological stress suppresses host resistance to infection. To investigate this issue, we prospectively studied the relation between psychological stress and the frequency of documented clinical colds among subjects intentionally exposed to respiratory viruses. METHODS: After completing questionnaires assessing degrees of phychological stress, 394 healthy subjects were given nasal drops containing 1 of 5 respiratory viruses (rhinovirus type 2, 9, or 14, respiratory syncytial virus, or coronavirus type 229E), and an additional 26 were given saline nasal drops. The subjects were then quarantined and monitored for the development of evidence of infecton and symptoms. Clinical colds were defined as clinical symptoms in the presence of an infection verified by the isolation of virus or by an increase in the virus-specific antibody titer. RESULTS: The rates of both respiratory infection ($p < 0.005$) and clinical colds ($p < 0.02$) increased in a dose-response manner with increases in the degree of psychological stress. Infection rates ranged from approximately 74% to approximately 90%, according to levels of psychological stress, and the incidence of clinical colds ranged from approximately 27% to 47%. These effects were not altered when we controlled for age, sex, education, allergic status, weight, the season, the number of subjects housed together, the infectious status of subjects sharing the same housing, and virus-specific antibody status at baseline (before challenge). Moreover, the associations observed were similar for all five challenge viruses. Several potential stress-illness mediators, including smoking, alcohol consumption, exercise, diet, quality of sleep, white-cell counts, and total

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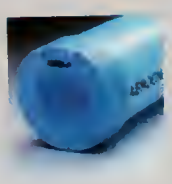

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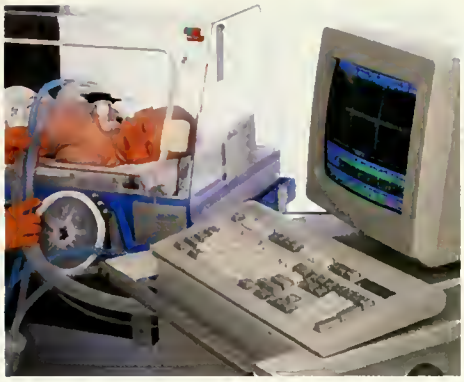

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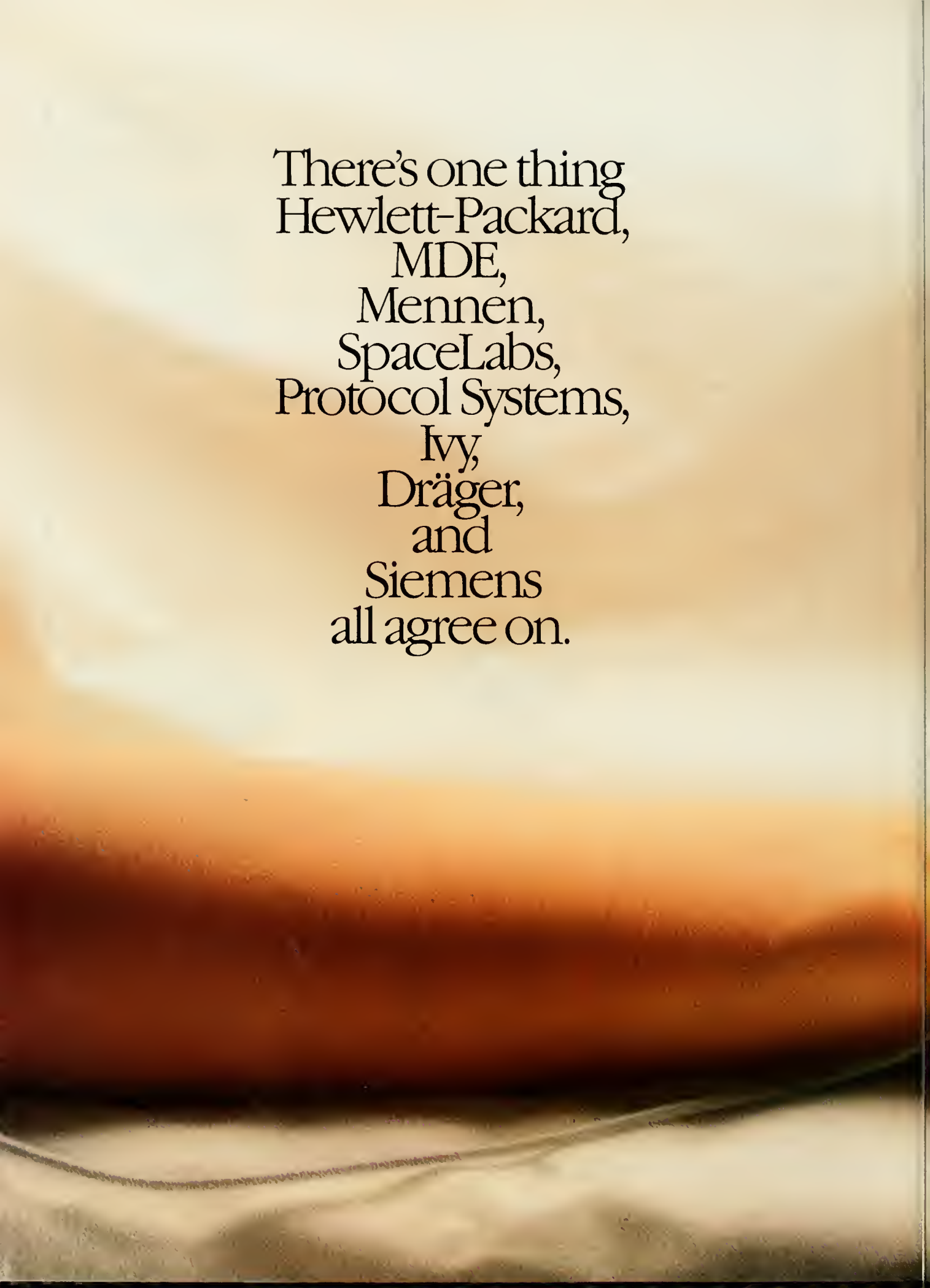
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Pulmonary Dysfunction in Surgical Conditions of the Newborn Infant—DK Nakayama, R Mutich, EK Motoyama. Crit Care Med 1991; 19:926.

OBJECTIVE: To describe the pathophysiology of surgical conditions that are associated with respiratory insufficiency in the newborn infant. DESIGN: Survey. SETTING: Newborn ICU in a children's hospital. PATIENTS: 24 newborn infants (1 to 28 days old) who required endotracheal intubation and mechanical ventilation for operative procedures or postoperative ventilatory support. INTERVENTIONS: Flow-volume curves obtained by manual inflation of the lungs, followed by forced deflation by negative pressure, and by passive expiration, under sedation and pharma-cologic paralysis. MEASUREMENTS: Deflation flow-volume curves and passive expiratory curves were measured. Pulmonary function testing before and after bronchodilator administration (n = 11) began midway during the study period. Term and preterm groups served as controls. MAIN RESULTS: Forced vital capacity (FVC) was decreased in all groups with surgical disease as follows: abdominal wall defects and necrotizing enterocolitis groups to 48.3% and 62.1% that of preterm, respectively; pulmonary hypoplasia group to 55.5% that of term ($p < 0.05$). Maximal expiratory flow at 25% of FVC decreased in all groups: abdominal wall defects and necrotizing enterocolitis group, to 36.8% and 37.9% that of preterm, respectively ($p < 0.05$); pulmonary hypoplasia group, 20.0% that of term ($p < 0.05$). The ratio of maximal expiratory flow at 25% of FVC divided by FVC was significantly decreased in necrotizing enterocolitis and pulmonary hypoplasia groups compared with that of preterm and term groups, respectively, but not in the abdominal wall defects group. Maximal expiratory flow at 25% of FVC, but not FVC, increased significantly (36%, $p < 0.05$) after bronchodilator nebulization, indicating the presence of airway reactivity. Respiratory system compliance was decreased significantly ($p < 0.05$) in all surgical disease groups compared with the term group. CONCLUSIONS: Bronchial reactivity contributes to decreased maximal expiratory flow at 25% of FVC, a feature also seen in premature infants with respiratory distress syndrome who later develop bronchopulmonary dysplasia. Babies who require chronic ventilatory support after operation and who have developed reactive airways may benefit from the administration of bronchodilators during postoperative ventilatory management.

Inverse Ratio Ventilation in ARDS: Rationale and Implementation—TW Marcy, JJ Marini. Chest 1991;100:494.

Conventional ventilatory support of patients with the adult respiratory distress syndrome (ARDS) consists of volume-cycled ventilation with applied positive end-expiratory pressure (PEEP). Unfortunately, recent evidence suggests that this strategy, as currently implemented, may perpetuate lung damage by overinflating and injuring distensible alveolar tissues. An alternative strategy—termed inverse ratio ventilation (IRV)—extends the inspiratory time, and, in concept, maintains or improves gas exchange at lower levels of PEEP and peak distending pressures. There are two methods to administer IRV: (1) volume-cycled ventilation with an end-inspiratory pause, or with a slow or decelerating inspiratory flowrate, or (2) pressure-controlled ventilation applied with a long inspiratory time. There are several real or theoretical problems common to both forms of IRV: excessive gas-trapping; adverse hemodynamic effects; and the need for sedation in most patients. Although there are many anecdotal reports of IRV, there are no controlled studies that compare outcome in ARDS patients treated with IRV as opposed to conventional ventilation. Nonetheless, clinicians are using IRV with increasing frequency. In the absence of well-designed clinical trials, we present interim guidelines for a ventilatory strategy in patients with ARDS based on the literature and our own clinical experience.

Modified Emerson CPAP, T-Piece Circuit for Use in the Multiplace Hyperbaric Chamber—BA Youn, R Houseknecht. J Hyperbaric Med 1991;6(2):101.

As the field of hyperbaric medicine continues to grow, treatment of the critically ill patient requiring respiratory support becomes a frequent occurrence. Many patients are treated with either continuous positive airway pressure (CPAP) or T-piece supplemental oxygen. Existing systems through ventilators may have significant work of breathing associated with the type of demand valve and circuit. This work of breathing depends on inspiratory flow demands of the patient and supply flow limits. Similar problems exist for T-piece circuits that utilize demand valves such as an A14 regulator with peak flow of only 60 L/min. In addition, because exhaled gases must be scavenged, both rebreathing of exhaled gases or negative end-expired pressure are potential problems. This has led to a modification of an Emerson demand-valve reservoir with an exhaled gas scavenging system for use within the multiplace chamber. This system can be set up as a CPAP or T-piece sys-

tem. The reservoir bag ensures adequate volume and flows with a backup demand flow capable of 120 L/min with minimal trigger pressure. This system has been tested to 6 absolute atmospheres in a multiplace chamber and is fairly easy and inexpensive to assemble. A disconnect, pressure loss, and minute ventilation alarm is available in addition to continuous respiratory rate and tidal volume monitoring.

Wheezing in a Commercial Diver due to Disinfectant—SJ Watt. Undersea Biomed Res 1991;18:347.

A case is described of a saturation diver with no previous history of asthma who repeatedly developed work-related symptoms of asthma at pressure, which appear to be causally related to the use of dichlorophen as a disinfectant agent. Although challenge tests were negative, suggesting that dichlorophen may have been acting as an irritant rather than as a sensitizer, the symptoms were abolished by the use of an alternative disinfectant agent. The potential importance of this effect in a diver is discussed, and the case highlights the importance of the use of nontoxic agents in the diving environment.

Treatment of Bronchial Asthma with Terbutaline Inhaled by Conespacer Combined with Positive Expiratory Pressure Mask—E Frischknecht-Christensen, O Norregaard, R Dahl. Chest 1991;100:317.

The influence of positive expiratory pressure (PEP) applied during inhalation of a B_2-agonist in treatment of bronchial asthma was investigated in a randomized crossover study with 2-week treatment periods. In one period, 2 puffs (0.5 mg) of terbutaline was given from a metered dose inhaler and inhaled through a device consisting of a conespacer connected to a face mask giving PEP (10 to 15 cm H_2O). In a second period, terbutaline 0.5 mg was inhaled similarly but without PEP, and in a third period placebo spray was inhaled with PEP. Treatments were given 3 times daily. Peak expiratory flow (PEF) was measured before and after each inhalation and symptom scores for dyspnea, cough, and mucus production were noted in a diary. All treatments increased PEF significantly ($p < 0.0001$). The mean increase was 32 L/min during treatment with terbutaline and PEP. This was greater than the increase of 25 L/min during terbutaline treatment ($p = 0.005$). The increase in PEF during terbutaline treatment was significantly higher than the achieved 18 L/min during PEP ($p = 0.026$). The study showed improved bronchodilation when PEP was combined with inhalation of B_2-agonist compared with B_2-agonist alone.

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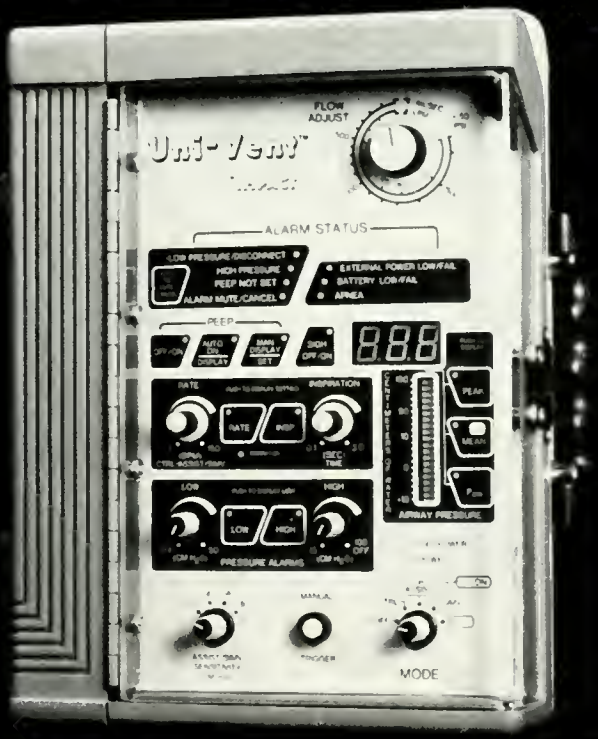

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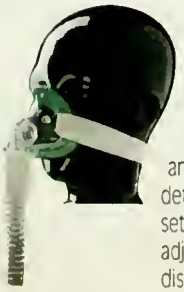

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Sweeter Is Not Necessarily Better

The impact of total and, more specifically, carbohydrate calories on respiratory function has been the focus of much research and attention (and some controversy) during the past decade. The recognition that malnutrition leads to increased morbidity and mortality has led to the development of artificial nutrition support via enteral and parenteral routes.

Of particular interest to those caring for patients with respiratory compromise are the studies such as those by Bassili et al[1] that have demonstrated the salutary effects of nutrition support in successful weaning from ventilators.[2] But the zeal and enthusiasm of the mid-1970s for the indiscriminate provision of carbohydrate and total calories were quickly dampened by reports such as those of Askanazi et al[3] that described the "glucose overload" syndrome and of Covelli et al[4] and Dark et al[5] that described respiratory failure and hypercapnia associated with overfeeding. As the policy of "more is not necessarily better" began to be implemented, attention was also drawn to the qualitative contribution of nonprotein calories provided to the patient with pulmonary compromise. The study by Kemper and Weissman[6] reported in this issue of RESPIRATORY CARE highlights the importance of including in the daily calorie counts heretofore ignored carbohydrate calories from exogenous liquids other than enteral and parenteral formulations. The results of the study provide a refinement in approach to the patient who is respiratory compromised. The study should serve as a point of departure for future considerations in the management of the critically ill patient.

Recent work suggests that maintenance of relatively normal plasma glucose levels may prevent the potential for glycation of immunoglobulins.[7] Although earlier recommendations were made for the substitution of lipids as a source of nonprotein calories, caution as to amount and type should be exercised in the light of recent work suggesting potential immunosuppressive effects of the currently available lipid emulsions when used in excess or infused rapidly.[8] We believe that until more is known about structured lipids (composed of fatty acid chains of varied lengths) and the role of increased amounts of fish oil, the provision of lipids in a 'low and slow' mode is prudent. Early feeding through the gastrointestinal tract is also strongly recommended.[9,10]

Other potential nutrition support interventions of still only hypothetical benefit to the subject with respiratory compromise have been summarized elsewhere.[11] Lastly, regardless of the nutrition support intitiated, close patient monitoring by a multidisciplinary team to measure clinical outcome is essential for the achievement of optimum nutrition.[12]

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A Comparison of Two Methods of Preoxygenation during Endotracheal Suctioning

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A new single-lumen oxygen-insufflation catheter designed to alternately deliver oxygen or suction was evaluated to determine whether its use could prevent episodes of hypoxemia during endotracheal suctioning. METHODS & MATERIALS: Insufflation-catheter suctioning was compared to resuscitation-bag suctioning in 23 adult patients (F_{IO_2} 0.30 to 0.50) from the medical, surgical, and neurological ICUs. Patients were selected for the study if we were able to obtain informed consent and if they were intubated with a ≥ 7.5-mm-ID endotracheal tube or tracheostomy tube, had an arterial cannula, and were on < 10 cm H_2O PEEP. All suctioning episodes consisted of two suction passes with 10 seconds of continuous suction at −120 torr. For the conventional method, a resuscitation bag was used to deliver 5 breaths of 100% O_2 (before and after the 2 10-second suctioning passes). For the insufflation method, O_2 was delivered at 15 L/min through the catheter for 15 seconds prior to the first suctioning, the patient was reconnected to the ventilator for 30 seconds after suctioning, and the procedure was repeated. Each subject served as his/her own control and was randomly assigned to the method used first. The P_{aO_2} and S_{aO_2} were recorded for each method prior to suctioning and at 30, 60, and 180 seconds following the procedure. RESULTS: ANOVA for repeated measures revealed a significant interaction between preoxygenation method and time for both P_{aO_2} and S_{aO_2} ($p < 0.001$). Oxygen insufflation prevented a clinically important change from baseline in mean P_{aO_2} and S_{aO_2} at all sampling times, while manual ventilation increased mean P_{aO_2} and S_{aO_2}. CONCLUSION: This study suggests that adequate arterial oxygenation can be maintained during suctioning using a single-lumen oxygen-insufflation catheter in patients who meet the above criteria. (Respir Care 1991;36:1195-1201.)

Mr Taft is Associate Professor and Director of Clinical Education, Ms Mishoe is Associate Professor and Chairman, Mr Dennison is Assistant Professor, and Dr Chaudhary is Professor of Medicine and Medical Director—Medical College of Georgia, Augusta, Georgia. At the time this study was performed Dr Lain was Clinical Instructor, Medical College of Georgia; he is currently Clinical Manager, Ohmeda Critical Care, Columbia, Maryland.

This study was supported by a grant from the VenTech Medical Manufacturing Corp, and all work was performed at the Medical College of Georgia.

A version of this paper was presented by Mr Taft at the RESPIRATORY CARE OPEN FORUM during the 1990 AARC Annual Meeting in New Orleans, Louisiana.

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Introduction

Endotracheal suctioning is a necessary, beneficial, and often frequently repeated procedure in the respiratory care of patients who require ventilatory support; however, there are inherent hazards. Suctioning-induced hypoxemia is a well-documented and significant risk[1-7] that can result in serious cardiac arrhythmias and even death.[8-11] To prevent possibly life-threatening hypoxemia, numerous techniques[4,5,12-15] and suction catheters have been used.[1,16-21] A number of studies suggest that the use of oxygen insufflation during the suctioning procedure is effective in preventing suctioning-induced hypoxemia.[16-21] Previous studies of insufflation catheters in adult patients have used double-lumen catheters, one lumen that insufflates oxygen and

the other through which suction is applied.[4,16-20] We undertook this study to evaluate whether a new single-lumen oxygen-insufflation catheter could prevent hypoxemia during endotracheal suctioning in a sample of adult patients.

Methods and Materials

Twenty-three adult patients were selected from the medical, surgical, and neurological ICUs at the Medical College of Georgia. The protocol was approved by the Human Assurance Committee. All patients who (1) were intubated with at least a 7.5-mm-ID endotracheal tube or tracheostomy tube, (2) had an indwelling arterial catheter, and (3) were receiving less than 10 cm H_2O PEEP were considered candidates and were studied if we were able to obtain informed consent. Patient demographic data are shown in Table 1.

All patients were suctioned by a conventional method (resuscitation bag and conventional catheter) and by the new technique using the insufflation catheter. Each patient served as his or her own control, and the method to be used first was randomly assigned. At least a 1-hour rest period was allowed between the use of one technique and the other. Each suctioning episode consisted of two 10-second suctioning passes with continuous suction applied at –120 torr. Patients were suctioned only when needed as determined by the nurses and respiratory therapists. With the conventional method, patients were disconnected from the ventilator and were manually ventilated with 100% O_2 for 5 breaths prior to continuous suctioning for 10 seconds with a standard 14-French (Fr) thumb-vent suction catheter. Manual ventilation with 100% O_2 was repeated before the second suctioning pass and again following the second pass. In the experimental method, O_2 was delivered at 15 L/min through the insufflation catheter for 15 seconds prior to suctioning with a 14-Fr single-lumen insufflation catheter. The patient was reconnected to the ventilator for 30 seconds following suctioning, and the procedure was repeated.

Arterial blood samples were analyzed and vital signs measured. The results were recorded for each subject for each method prior to preoxygenation and suctioning and also at 30, 60, and 180 seconds following each procedure. All blood samples were placed on ice and analyzed using a blood gas analyzer and CO-oximeter maintained according to manufacturer's specifications.

Table 1. Diagnosis, Ventilator Mode, Oxygen Concentration Delivered (F_{DO_2}), Positive End-Expiratory Pressure (PEEP), and Endotracheal-Tube (ETT) Size for the 23 Patients Studied

Patient/Diagnosis	Ventilator Mode	F_{DO_2}	PEEP (cm H_2O)	ETT (mm)
1 Guillain-Barré	A/C*	0.35	5	8.5
2 Gunshot wound to chest	IMV	0.40	5	9.0
3 ARDS	A/C	0.40	0	8.5
4 Congestive heart failure	IMV + PS	0.50	5	8.0
5 Sepsis	IMV	0.40	0	7.5
6 Emphysema	A/C	0.45	0	8.0
7 Sepsis	IMV	0.40	0	7.5
8 Closed-head injury	A/C	0.40	5	7.5
9 Small-bowel obstruction	A/C	0.40	9	8.0
10 Open depressed skull fracture	IMV	0.50	0	7.5
11 Congestive heart failure	A/C	0.40	0	7.5
12 Pneumonia	IMV	0.40	5	10.0
13 Closed-head injury	IMV	0.35	5	10.0
14 25% BSA burn†	IMV	0.40	8	9.0
15 Guillain-Barré	IMV	0.40	0	8.0
16 Aspiration	A/C	0.40	3	7.5
17 COPD	A/C	0.45	0	7.5
18 Closed-head injury	CPAP	0.40	6	10.0
19 Subarachnoid hemorrhage	T-tube	0.40	0	7.5
20 Guillain-Barré	IMV	0.40	5	8.5
21 Quadriplegia	IMV + PS	0.30	5	8.0
22 Myasthenia gravis	IMV	0.40	5	8.0
23 COPD	A/C	0.40	0	7.5

* A/C = assist/control, IMV = intermittent mandatory, IMV + PS = IMV + pressure support, CPAP = continuous positive airway pressure, T-tube = spontaneous ventilation with humidified gas through a Briggs adapter.
† BSA = body surface area.

Statistical analysis was performed using repeated measures analysis of variance (ANOVA). One patient record had a missing datapoint, and was not included in the statistical analysis. A p value < 0.05 was considered statistically significant.

Results

Data analysis revealed a significant interaction between preoxygenation method and time on P_{aO_2} ($p < 0.001$) as shown in Figure 1. For each patient, baseline values and maximum changes in P_{aO_2} with each method are listed in Table 2. When manual ventilation, or preoxygenation 'bagging,' was incorporated, P_{aO_2} increased from a mean (SD) baseline of 106 (35) torr to a mean maximum of 141 (48) torr at 30 seconds following the procedure. With insufflation, P_{aO_2} dropped from a mean baseline of 107 (29) torr to a mean minimum of 104 (31) torr at 60 seconds. At 180 seconds, mean P_{aO_2} was 6 torr above baseline with the manual ventilation method and 2 torr above baseline values with the insufflation method.

When we analyzed the data based on baseline P_{aO_2}, two distinct patterns emerged. When insufflation was used, as shown in Figure 1, if the patient's baseline P_{aO_2} was > 95 torr, the mean P_{aO_2} decreased from 130 (21) to 123 (32) torr. However, if the patient's baseline P_{aO_2} was < 95 torr, the mean P_{aO_2} increased from 80 (8) to 84 (11) torr. Manual ventilation produced increases in mean P_{aO_2} whether the patient had a baseline P_{aO_2} > or < 95 torr, as shown in Figure 1.

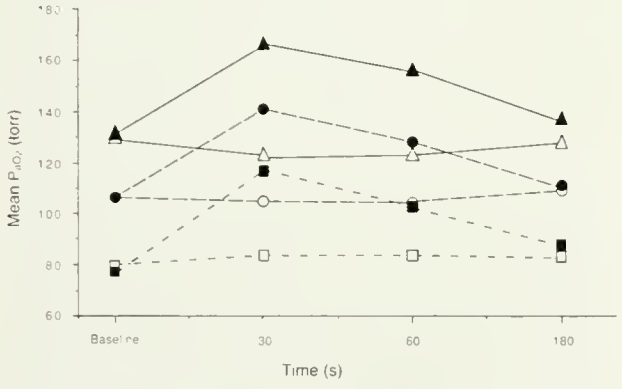

Fig. 1. Changes in mean P_{aO_2} over time using 'bagging' or insufflation as a method of preoxygenation. Insufflation = ---O---; manual ventilation = ---●---; insufflation-baseline P_{aO_2} < 95 torr = ---□---; manual ventilation-baseline P_{aO_2} < 95 torr = ---■---; insufflation-baseline P_{aO_2} > 95 torr = ---Δ---; manual ventilation-baseline P_{aO_2} > 95 torr = ---▲---.

Table 2. Maximum Changes in P_{aO_2} with Two Preoxgenation Suctioning Methods

Patient No.	Manual Inflation* Baseline P_{aO_2}	Manual Inflation* Maximum Change in P_{aO_2}	Insufflation† Baseline P_{aO_2}	Insufflation† Maximum Change in P_{aO_2}
1	75‡	18	91	–10
2	149	–26	133	–25
3	96	–23	107	–24
4	97	40	110	–13
5	72	147	78	3
6	76	–16	68	12
7	131	46	131	–17
8	174	–41	166	–35
9	93	–21	105	–21
10	168	59	170	29
11	63	52	84	6
12	126	47	117	–17
13	120	30	137	26
14	92	14	90	–2
15	128	5	124	–29
16	74	45	74	10
17	103	84	69	42
18	81	17	79	–4
19	85	49	81	7
20	161	74	120	23
21	126	78	138	25
22	76	35	75	–4
23	65	65	89	–7
Range	63 to 174	–41 to 147	68 to 170	–35 to 42

* Each suctioning episode = 5 breaths of 100% O_2, 10-second suctioning, 5 breaths of 100% O_2, repeated once.

† Each suctioning episode = 15 seconds of O_2 at 15 L/min prior to suctioning, 10-second suctioning, 30 seconds of ventilation via ventilator, repeated once.

‡ All values are in torr.

A significant interaction also was seen between preoxygenation method and time on S_{aO_2} ($p < 0.001$) as shown in Figure 2. With manual ventilation, S_{aO_2} increased from a mean baseline of 95.1 (2.3) % to a mean maximum of 96.2 (1.3) % at 30 seconds. With insufflation, S_{aO_2} decreased from a

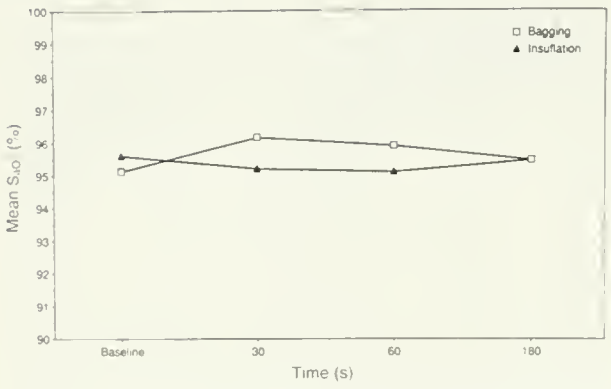

Fig. 2. Changes in mean S_{aO_2} over time using manual ventilation (---□---) or insufflation (---▲---) as a method of preoxygenation.

mean baseline of 95.6 (1.5) % to a mean minimum of 95.1 (1.6) % at 60 seconds. The maximum decrease in S_{aO_2} was 2% (from 94.7 to 92.7, Patient 29) with insufflation and 2.1% for bagging (from 95.2 to 93.1, Patient 9). The lowest S_{aO_2} recorded was 90.4% in Patient 5 with insufflation. With either method, S_{aO_2} remained relatively stable throughout the study and had returned almost to baseline by 180 seconds.

Using time and preoxygenation method as independent variables, we saw no significant main effects or interactions for P_{aCO_2}, pH, or heart rate.

Five of the 23 patients had decreases from baseline in P_{aO_2} when manual ventilation was used, whereas 13 of 23 had decreases when insufflation was used (Table 2). However, no patient in our study experienced suctioning-induced hypoxemia when oxygen insufflation was used. Although Patients 18 and 22 had relatively low baseline P_{aO_2}, insufflation was associated with only small decreases (4 torr). Patients 3 and 9 experienced marked decreases in P_{aO_2} when manual ventilation was used, although the changes in P_{aO_2} levels were similar for both techniques. Patient 6 had a decrease in P_{aO_2} with manual ventilation, but an increase in P_{aO_2} with insufflation.

The results of our study, as shown in Figures 1 and 2, indicate that while an increase in both mean P_{aO_2} and mean S_{aO_2} occurred with manual ventilation, oxygen insufflation prevented a meaningful change from baseline in mean P_{aO_2} and mean S_{aO_2}, at all sampling times.

Discussion

The idea that oxygen insufflation can maintain adequate arterial oxygenation is not new.[1,22] More than 30 years ago, Boba et al[1] introduced the technique of oxygen insufflation during suctioning, and concluded that oxygen insufflation at a rate of 4 L/min prevented hypoxemia during simple apnea and during apnea with simultaneous endotracheal suctioning. Other studies have also demonstrated that low-flow oxygen insufflation at 5 L/min is effective in preventing hypoxemia during suctioning.[16,21] However, Fell and Cheney[15] did not arrive at this same conclusion—possibly due to the degree of pulmonary impairment in their patients, the low oxygen-insufflation rate (5 L/min), and differences in the suction flowrates. Recent studies[17-20] have used higher flows of oxygen (from 10-15 L/min) with positive results and no adverse effects. The optimal oxygen flowrate for use with insufflation has yet to be determined. We chose 15 L/min oxygen insufflation based upon our own preliminary studies and the work of others.[17,18] Others have limited the oxygen insufflation to 10 L/min, based upon subjective signs of patient distress and concern over generating an increased airway pressure distal to the catheter.[19] Excessive pressures can be generated if there is inadequate venting of the insufflated gas. In our preliminary studies using a test lung with a compliance of 0.1 L/cm H_2O, we determined that less than 10 cm H_2O pressure was generated distal to the catheter when insufflating O_2 at 15 L/min through a 14-Fr catheter and a 7.5-mm-ID endotracheal tube (that is, cross-sectional area of suction catheter to cross-sectional area of endotracheal tube, or SC:ETT, < 0.4). This has been verified by Tiffin et al,[23] using the same single-lumen catheter we studied. They demonstrated that with the SC:ETT = 0.5, less than 10 cm H_2O pressure is generated with insufflation of 15 L/min through a 14-Fr catheter. Although studies have demonstrated that oxygen flows of 5-10 L/min are effective in preventing suctioning-induced hypoxemia,[19-21] we believe a higher flow may achieve better oxygenation in adults without posing any greater risks.

Previous studies in adults have used constructed (ie, made in-house) or commercially available double-lumen catheters, to deliver oxygen and suction either simultaneously or alternately. In this study,

we assessed the effectiveness of a single-lumen oxygen-insufflation catheter in alternately delivering oxygen and suction. Graf and co-workers[21] used this single-lumen device in a group of infants, and concluded that this new catheter reduces the number of hypoxic and hyperoxic episodes and may represent a safe alternative to suctioning with preoxygenation. These authors also noted that because only a single lumen was required, the outside diameter of the catheter could be reduced and thus could accommodate much smaller endotracheal tubes,[21] which presents a particular advantage in the respiratory care of neonatal and pediatric patients. Also, we believe that having the entire lumen available can provide additional benefits when suctioning patients with thick and/or large amounts of secretions, although we did not specifically test this aspect. In further studies, the quantities of sputum removed with a single-lumen catheter could be compared to quantities removed with a double-lumen catheter. A double-lumen catheter of a given outside diameter or cross-sectional area has a smaller suction lumen than a single-lumen catheter of the same outside diameter, which decreases the ability to suction thick or large amounts of secretions. However, we did notice that when suction to this single-lumen catheter was released, thin secretions on occasion were blown out the end of the catheter. This is clinically undesirable, but might be avoided if a neutral "off" position was added to the design where there is neither suction nor oxygen flow.

It has been shown[4,12,24,25] that when adequately controlled, manual ventilation is an effective way to prevent hypoxemia associated with suctioning. However, in clinical practice, the volume and pressure of the delivered breath is often variable and difficult to control.[26] With the delivery of an unknown tidal volume at an unknown peak pressure, the potential for barotrauma or hypoventilation exists. Bodai et al[18] and Brown et al[5] have addressed concerns about complications from manual hyperventilation to unknown volumes and pressures. If clinicians continue to use manual resuscitators to preoxygenate patients prior to suctioning, attention must be given to determining whether the volume capacity of each bag is suitable and whether the ventilation technique of personnel is appropriate.[26,27]

In addition, conventional hyperoxygenation techniques are associated with agitation, tachycardia, tachypnea, and uncontrolled coughing.[6,18] Although the procedure is intended to be gentle, rapid ventilation and suctioning seem to add to the patient's stress. Harken[14] addressed the issue of harm with suctioning by advocating "gentle" augmentation of tidal volume and handling of the endotracheal tube to prevent distress and ineffective cough. Also, the use of a manual resuscitator often requires additional equipment, time, and manpower. We agree with Smith and co-workers[19] who have proposed that the oxygen-insufflation catheter can save practitioner time. Hess and Goff have shown that it is difficult to achieve adequate tidal volumes when squeezing a resuscitation bag with one hand.[26] One-hand ventilation can be especially difficult when the clinician is trying to maintain sterility of the suction catheter at the same time. In order to assure adequate tidal volumes with manual ventilation, two clinicians may be needed when suctioning is performed. We did not find a large difference in the time required to perform suctioning by each method, but because our conventional preoxygenation method uses two clinicians, personnel time is increased. If an institution now uses two persons when suctioning, substitution of an oxygen-insufflation catheter would reduce required personnel time, suggesting considerable manpower savings. In these times of personnel shortages, we believe that the oxygen-insufflation catheter offers an advantage over conventional preoxygenation methods.

In Conclusion

The results of our study and the work of others suggest that oxygen insufflation is a valid alternative to hyperinflation-preoxygenation methods when the goal is to prevent suctioning-induced hypoxemia in patients who are not severely hypoxemic.[1,16-21] We did not study patients requiring a PEEP level greater than 10 cm H_2O or an F_{IO_2} greater than 0.50. Further studies are needed to determine the optimal oxygen-insufflation rates for use during endotracheal suctioning and to assess the efficacy of this alternative suctioning method in more severely hypoxemic patients on higher levels

of oxygen or PEEP. Although several questions remain, we share the belief that oxygen insufflation is an acceptable alternative to manual ventilation for most patients,[18] particularly because conventional preoxygenation techniques pose hazards and are not universally practiced. In summary, sufficient clinical data exist to support the statement that oxygen insufflation can prevent suctioning-induced hypoxemia in patients who are not severely hypoxemic and provide a convenient means for endotracheal suction.

ACKNOWLEDGMENTS

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PRODUCT SOURCES

Insufflation Suction Catheter:
VenTech ISC, VenTech Inc, Ontario, Canada

Standard Suction Catheter:
Reg-U-Vac, Bard Parker, Lincoln Park NJ

Blood Gas Analyzer:
Corning 170 Blood Gas Analyzer, Ciba-Corning Diagnostics Corp, Medfield MD

CO-Oximeter:
Corning 2500 CO-Oximeter, Ciba-Corning Diagnostics Corp, Medfield MD

Test Training Lung:
Michigan Instruments Inc, Grand Rapids MI

Vacuum Regulator:
1251 Intermittent Suction Unit (ISU), Ohmeda Critical Care Maryland, Columbia MD

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The Influence of Intravenous Dextrose Infusions on the Carbohydrate Intake of Critically Ill Patients Receiving Nutritional Support

Marcia Kemper BA CRTT and Charles Weissman MD

BACKGROUND: Because carbohydrate metabolism results in the production of carbon dioxide (CO_2), spontaneously breathing patients with the inability to increase minute ventilation ($\dot{V}_E$) in the face of an increase in CO_2 load from carbohydrate intake may develop CO_2 retention and respiratory acidosis. Also, control of carbohydrate intake in patients with diabetes mellitus is necessary. Critically ill patients often receive intravenous 5% dextrose infusions in addition to their nutritional support regimens for medication delivery and systemic hydration. We sought to quantitate the contribution of such infusions to the total caloric intake and the proportion of carbohydrate provided. METHODS: We measured resting energy expenditure daily by direct calorimetry and quantified the contribution of the dextrose solutions to carbohydrate and total caloric intake in a group of 17 critically ill, mechanically ventilated postoperative patients studied for a total of 143 patient-days. Total carbohydrate intake, total caloric intake, caloric intake from nutritional support formulations, and caloric intake from intravenous 5% dextrose were computed. 5% dextrose was provided on 123 of 144 study-days, with intake from intravenous 5% dextrose ranging from 20 to 934 Kcal/day with mean (SD) of 150 (140), which represented from 1-43% of the total caloric intake 12 (18)%. RESULTS: 5% dextrose intake provided an average of 12% of all calories and increased the proportion of carbohydrate-to-total calories from 37 to 50%. CONCLUSION: The amount of intravenous 5% dextrose should be considered when designing and monitoring nutritional support regimens, particularly in patients with marginal pulmonary function. (Respir Care 1991;36:1202-1206.)

Background

Nutritional intake can increase respiratory requirements.[1] Carbohydrates, the predominant substrate in most nutritional support regimens, are metabolized to carbon dioxide (CO_2), which must then be excreted by the respiratory system. In addition, protein ingestion or infusion increases metabolic rate, minute ventilation ($\dot{V}_E$), and respiratory drive.[2-5] The patient with a dysfunctional respiratory system may be unable to spontaneously increase ventilation in the face of increasing demand. Failure to increase $\dot{V}_E$ after a large carbohydrate load can lead to retention of CO_2 and respiratory acidosis[6] in the patient being ventilated at a fixed $\dot{V}_E$ or breathing spontaneously. Consequently, when the decision is made to feed a critically ill patient, care should be exercised to provide the correct amount and proportion of nutritional substrates to minimize the effects on respiration. Patients experiencing respiratory difficulties or being readied for weaning may require

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nutritional formulas low in carbohydrates to reduce the demand placed on the respiratory system. This is usually accomplished by increasing the fat content and decreasing the carbohydrate intake. Formulas containing up to 70% of the nonprotein calories as fat have been administered,[7] although more commonly nonprotein calories are provided as 30-50% fat and the rest as carbohydrate.

In critically ill patients, carbohydrates are administered not only as part of nutritional support regimens but also in intravenous dextrose infusions. The latter are the omnipresent 5% dextrose in water and 5% dextrose in saline solutions used for volume expansion, for medication dilution, and to ensure that intravenous catheters remain patent.

We examined the contribution of these 5% dextrose infusions to the total caloric and carbohydrate intake in a group of mechanically ventilated patients receiving parenteral and/or enteral nutrition. The increase in carbohydrate and caloric intake provided by these 5% dextrose infusions may be important, especially for patients in whom the carbohydrate intake should be limited such as those with a compromised respiratory system or diabetes mellitus.

Methods

We studied 17 critically ill, ventilator-dependent, postoperative surgical patients, from the Surgery-Anesthesiology Intensive Care Unit of the Columbia-Presbyterian Medical Center in New York City, who were receiving enteral and/or parenteral nutritional support. Study days totaled 143, and patient ages ranged from 18-82 years (average 62 years). For each 24-hour period the intake of clinical nutrition (ie, enteral and parenteral formulas) and 5% dextrose was recorded and analyzed to determine the total caloric intake and the proportion of fat, carbohydrate, and protein provided. All sources of carbohydrate intake were identified and the amount of carbohydrate administered quantitated.

Each patient's resting energy expenditure (REE) was measured daily using either the SensorMedics Deltatrac or the Engstrom metabolic computer, Erica ventilator, and Eliza capnometer.* When the Deltatrac[8] was used, it was interfaced to either a Bear 1 or 2 ventilator. The air and oxygen outlets of the Bear ventilators were provided with gas from an external air-oxygen blender.[9] The inspiratory-gas sampling line of the Deltatrac was placed on the outlet port of the ventilator's humidifier. The mixed expired gases were collected from the expiratory port of the Bear ventilator and conducted to the mixing chamber of the Deltatrac via 6 feet of 22-mm tubing. The barometric pressure was read each day from a standard mercury barometer and the Deltatrac adjusted accordingly. The O_2 and CO_2 analyzers were calibrated with standard gas mixtures to exact gas percentages of 96.00 and 4.00%, respectively. The Engstrom metabolic measurement system incorporates a dedicated sampling system that was used in this study. The Erica ventilator was volume calibrated and the metabolic computer was checked according to manufacturer's specifications. The oxygen analyzer in the computer was given a two-point calibration to room air and 100% oxygen. The Eliza capnometer was calibrated using a calibration gas.

The total caloric intake, the total carbohydrate intake, and the caloric intake of carbohydrate from nutritional support formulations and intravenous 5% dextrose infusions were computed. The data would be expressed as mean and SD. Proportions are reported as the mean and SD of individual measurements—not as the proportion of the mean of all measurements. Differences between the measured REE and the total caloric intake would be tested by Student's *t* test. The study was approved by the Institutional Review Board of the Columbia-Presbyterian Medical Center.

Results

Intravenous dextrose was administered on 123 of the 143 study days; on 4 study days it was the sole nutrient provided. The nutritional intake is listed in Table 1. Caloric intake from intravenous 5% dextrose ranged from 20-934 Kcal/day (150 ± 140). The contribution of the 5% dextrose intake to total caloric intake ranged from 1-43%, 12 (18) %. There was no significant difference between the measured resting energy expenditure and total caloric intake.

* Suppliers are identified in the Product Sources section at the end of the text.

Table 1. Nutritional Intake for Mechanically Ventilated Patients during 143 Study Days

	Mean	SD
Measured REE (Kcal/day)*	1718	358
Total caloric intake (Kcal/day)†	1820	594
Total caloric intake/measured REE	1.08	0.34
Intravenous 5% dextrose intake (Kcal/day)	150	140
Other carbohydrate intake (Kcal/day)	672	338
Total carbohydrate intake (Kcal/day)	822	328
Intravenous 5% dextrose/total caloric intake	0.12	0.18
Other carbohydrate intake/total caloric intake	0.37	0.16
Total carbohydrate intake/total caloric intake	0.49	0.18
Total lipid intake/total caloric intake	0.37	0.14
Total protein intake/total caloric intake	0.14	0.04
Total carbohydrate intake/measured REE	0.50	0.22
Respiratory quotient (RQ)	0.90	0.07

* REE = resting energy expenditure.

† All ratios are means of individual patient values rather than of whole means.

Example:	Value	Value	A/B
	1	3	0.33
	2	4	0.5
	A = 1.5	B = 3.5	0.41665 = A/B = ratio of whole means

1.5/3.5 = 0.42857 = means of individual patient values.

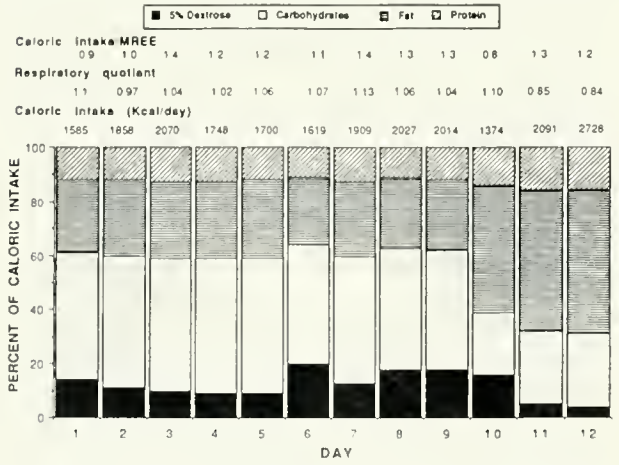

Fig. 1. The total caloric intake and proportions of fat, protein, carbohydrates (not delivered as 5% dextrose solutions), and 5% dextrose are illustrated for a patient who received enteral nutrition for 12 days. Note the change to a high fat diet on Day 10.

An example of the influence of 5% dextrose on caloric intake can be found in Figure 1, which shows a 12-day regimen for one patient. In only that one patient was the respiratory quotient (RQ) above 1.0 for more than one day, due to a high carbohydrate intake that reached 80% of measured resting energy expenditure on Days 7-9 of the study. Respiratory changes were noted in this patient with respiratory rates of up to 30-34 breaths/min and minute ventilations of 18-20 L/min observed on Days 7-9 of the study. With the switch to a lower carbohydrate diet on Days 10-12, the respiratory rate decreased to 20 breaths/min.

Discussion

In the 17 patients studied, the intravenous 5% dextrose solutions administered provided an average of 12% of the total caloric intake. This represented an increase in the mean contribution of carbohydrate calories to 50%, from the 37% of the nutritional formulas alone. This increase may be important and needs to be taken into consideration when there is reason to limit carbohydrate intake (such as in patients with diabetes mellitus, in those who have become very hyperglycemic following injury or sepsis, or those unable to adequately excrete carbon dioxide because of marginal respiratory function and who are breathing spontaneously or being weaned from mechanical ventilation).

Ingested carbohydrates are oxidized to CO_2 and water (a process that produces adenosine triphosphate, or ATP), converted to fat (lipogenesis), or stored as glycogen. Oxygen is consumed and CO_2 produced in equal amounts during the oxidation of glucose. The ratio of carbon dioxide production ($\dot{V}_{CO_2}$) to oxygen consumption ($\dot{V}_{O_2}$), or $\dot{V}_{CO_2}/\dot{V}_{O_2}$ (the respiratory quotient, RQ) for carbohydrate oxidation is 1.0. At rest, the oxidation of protein results in a $\dot{V}_{CO_2}/\dot{V}_{O_2}$, or RQ, of 0.8 while fat oxidation results in an RQ of 0.71. Thus, the fuel the body is metabolizing determines the RQ. Large quantities of carbohydrate administered either alone or as a part of a nutritional regimen result in an increase in $\dot{V}_{CO_2}$ and a rise in RQ. If sufficient food is administered to satisfy the patient's metabolic requirements and the patient has normal metabolic processes, net lipogenesis

may occur. Lipogenesis increases the $\dot{V}_{CO_2}/\dot{V}_{O_2}$ (as well as the absolute amount of CO_2 produced) by as much as a factor of 8. However, because only a small amount of ingested carbohydrate is converted to fat, the whole-body RQ has not been observed to exceed 1.25-1.30 even in situations in which subjects have been fed large carbohydrate loads.[10] (We used a metabolic cart that is able to measure only whole-body $\dot{V}_{CO_2}$ and $\dot{V}_{O_2}$.). But, when lipogenesis does occur, $\dot{V}_{CO_2}/\dot{V}_{O_2}$ rises above 1.0 and the absolute amount of CO_2 produced is increased. This is what has been reported when nutritionally depleted patients have been repleted on regimens containing amounts of carbohydrate that exceed REE.[11] If half the carbohydrate calories are replaced by fat, the RQ decreases because of reduced $\dot{V}_{CO_2}$. In the clinical arena, Covelli[6] observed that mechanically ventilated patients with fixed $\dot{V}_E$ when given large carbohydrate loads (2000-4000 Kcal/day) had significant increases in P_{aCO_2} with resultant respiratory acidosis. Decreasing the carbohydrate intake and/or substituting fat for some of the carbohydrates decreased $\dot{V}_{CO_2}$[12] and P_{aCO_2}.[6] Similar observations have been made by others.[13-15] Jannace et al found that patients given large carbohydrate loads over short time periods can suffer hypercapnia.[13] Dark et al[14] reported two cases in which aggressive nutritional support (excess calories and large carbohydrate loads) increased ventilatory demand so much that weaning from mechanical ventilation was compromised. Adequate CO_2 elimination is relatively easy to achieve in most mechanically ventilated patients, but excessive $\dot{V}_{CO_2}$ may become important when weaning is anticipated.[16]

Most carbohydrate-associated hypercapnia has been reported in patients with compromised ventilatory function who were unable to increase their $\dot{V}_E$ adequately. They also were being fed with excessive loads of carbohydrates and/or excessive total caloric intake in which the carbohydrate calories often exceeded the REE. This is in distinction to situations in which patients are able to increase their spontaneous $\dot{V}_E$ and, thus, are able to eliminate the additional carbon dioxide. For example, in Gieseke et al's study of resting patients with hypercapnia from chronic obstructive pulmonary disease,[17] the increase in $\dot{V}_{CO_2}$ caused by a carbohydrate load (920 Kcal administered orally) was handled with an increased $\dot{V}_E$ so that there was no increase in P_{aCO_2}. However, similar amounts of carbohydrate given to exercising COPD patients reduced their exercise capacity.[18,19] Therefore, in many patients, carbohydrate load is not an issue at rest because they are able to increase their respiratory elimination of CO_2. To avoid potential problems with elevated $\dot{V}_{CO_2}$ in critically ill patients, it is recommended that total caloric intake be limited to 1.2 times REE and that nonprotein calories be given as 45-60% fat with the rest being carbohydrate.[20] As a consequence, the enteral nutrition industry has developed formulas with reduced carbohydrate and increased fat content (57% fat, 43% carbohydrate). In the present study, there was no evidence of respiratory problems associated with feedings because an effort was made by the clinicians to avoid overfeeding and maintain an intake of equal amounts of carbohydrate and fat.

The present study points out that when a nutritional regimen low in carbohydrates is being designed, it is necessary to consider all nutritional intake not only the specific nutritional support regimen. Perhaps most important is the 5% dextrose that is infused routinely for a variety of reasons. Each liter of 5% dextrose contains 170 Kcal of carbohydrate (1 g dextrose = 3.4 Kcal). In our study, 5% dextrose was administered on 86% of the study days, with an average of a little over 1 liter infused per day. The amount of 5% dextrose infused varied from day to day depending on the need for intravenous medications and fluid resuscitation. Also, if the blood glucose concentration increased and was difficult to control, the amount of 5% dextrose infused was decreased. The 5% dextrose accounted for an average of 12% of all calories and increased the mean proportion of carbohydrate calories to total calories from 37% to 50%. Predictably, as the intake of the nutritional support formulation increased, the influence of the 5% dextrose on total and carbohydrate calories decreased.

Conclusion

The mean amount of intravenous 5% dextrose normally administered in the ICU should be considered when designing a nutritional support regimen.

PRODUCT SOURCES

Metabolic Carts:
Deltatrac, SensorMedics Corp, Yorba Linda CA
Engstrom metabolic computer, Gambro-Engstrom, Denver CO

Mechanical Ventilators:
Erica, Gambro-Engstrom, Denver CO
Bear 1 and Bear 2, Bear Medical Systems, Riverside CA

Capnometer:
Eliza, Gambro-Engstrom, Denver CO

Air-Oxygen Blender:
Bennett AO-1, Puritan-Bennett Corp, Carlsbad CA

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Manual Ventilation during Magnetic Resonance Imaging

William F Taylor BS RRT, Patrick D Pangburn MS RRT, and Alan Paschall MD

Mechanical ventilation during magnetic resonance imaging (MRI) requires a specially constructed ventilator that contains no ferromagnetic components; however, the expense of acquiring such a ventilator may not be warranted if projected use is infrequent. We adapted a Laerdal manual resuscitator to allow its use during MRI, and report the simulation and monitoring procedure that we developed and the successful ventilation of three pediatric patients with the device. (Respir Care 1991;36:1207-1210.)

Introduction

Magnetic resonance imaging (MRI) is employed to resolve questions related to the central nervous system that have gone unanswered by other imaging techniques.[1] The strong magnetic field generated by the imager requires that equipment within the imaging room contain no ferromagnetic components that might interfere with imager and equipment function or that might endanger personnel. Although a specially constructed ventilator that contains no ferromagnetic components is available, the expense of acquiring such a ventilator may not be warranted if projected use is infrequent.

We adapted a Laerdal manual resuscitator to allow its use during MRI. Because the imaging cylinder is too small to accommodate both patient and therapist, extension tubing (5-6 ft depending on imager design) is needed to cover the distance between the patient and the therapist after the patient has been moved into the imaging cylinder (Fig. 1). When a manual resuscitator is adapted for use during MRI, increased circuit dead space must be avoided. This precludes extension tubing proximal (toward the patient) from the resuscitator inflating-exhalation valve because such tubing would constitute increased dead space. Therefore, the inflating-exhalation valve must be detachable from the body (ie, 'bag') of the manual resuscitator to allow extension tubing to be placed between the inflating-exhalation valve and the resuscitator bag. Although many models of disposable resuscitator are available, we know of only two that allow extension tubing to be placed between valve and bag—the Laerdal and the Mercury CPR—and report here our experience with the Laerdal.[2]*

Description of Apparatus

We detached the low dead-space (approximately 8-10 mL) inflating-exhalation valve from the bag of the resuscitator, and inserted 66 inches of large-bore corrugated tubing (approximately 550 mL internal volume) between the valve and the bag. A tapered 22-mm-to-23-mm adapter is necessary to assure a snug fit between corrugated tube and resuscitator bag. The oxygen source, an MRI-compatible oxygen E-cylinder and regulator, was used in the imaging room. The oxygen-reservoir tubing on the manual resuscitator was kept in place to maximize oxygen delivery.

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*Suppliers are identified in the Product Sources section at the end of the text.

For infant ventilation, the extension is provided by Tygon tubing connected to the Laerdal bag with a universal 15-mm ID/22-mm OD adapter, a rubber connector, and a large ET-tube adapter (8-9 mm).

Fig. 1. A therapist uses modified Laerdal manual resuscitator during magnetic resonance imaging (MRI) of a ventilator-dependent child. Modification (with extension tubing and MRI-compatible oxygen cylinder and regulator) allows ventilation to continue after patient has entered the imaging cylinder.

Methods of Evaluation

Monitoring and Simulation

Prior to transport, simulation of ventilation anticipated during MRI is performed in the controlled environment of the ICU with an end-tidal or transcutaneous CO_2 (P_{tcCO_2}) monitor, pulse oximeter, and proximal airway pressure manometer in place to allow the therapist to modify oxygen flow and depth and frequency of bag compression to maintain oxygenation and ventilation comparable to that achieved with the ICU ventilator. Monitor adequacy is confirmed by blood gas analysis before transport. During transport and MRI, the therapist maintains the established pattern of ventilation and observes the patient closely. Oxygenation is monitored continuously in the imaging room by an MRI-compatible pulse oximeter.[3]

Application of Method

We have successfully supported three ventilator-dependent children during MRI using the modification and procedure described.

Case 1: A 4-year-old boy unconscious as a consequence of a pedestrian-motor vehicle accident was admitted to our pediatric intensive care unit (PICU) with a cervical collar in place. He was being manually ventilated via an oral endotracheal tube. Examination revealed multiple skin abrasions, lack of spontaneous respiratory effort, and Glasgow Coma Score of 6. He was placed on a Siemens Servo 900C ventilator, and blood gas values were normalized. When the patient regained consciousness, he was unable to move his extremities or demonstrate respiratory effort. Plain cervical-spine radiographs and computerized tomography failed to demonstrate cervical spine involvement. MRI was requested in an attempt to determine the location and extent of cord injury.

In the monitored environment of the PICU, a pulse oximeter and a P_{tcCO_2} monitor were placed on the patient and allowed to equilibrate. An arterial blood sample was obtained for analysis to validate the accuracy of the monitors. The patient was taken off the ventilator and manually ventilated for about 20 minutes with a pediatric Laerdal bag configured as previously described. The degree of chest expansion for a given peak pressure was noted, and the ventilation rate was kept constant. The peak inspiratory pressure, pulse oximeter saturation (S_{pO_2}), and P_{tcCO_2} were maintained at approximately the same level as during mechanical ventilation. Monitoring was continuous, and no clinically important changes were seen in heart rate (90 before, 100 after), blood pressure (98/48 before, 98/48 after), S_{pO_2} (100% before, 100% after), P_{tcCO_2} (46 before, 40 after). After 20 minutes of manual ventilation, blood gas values were within acceptable limits (pH 7.51, P_{aCO_2} 42, P_{aO_2} 373).

The patient was taken to MRI. The scan revealed contusion of the spinal cord at the craniocervical junction, without cord transection. Throughout the procedure, heart rate ranged from 90-100 and S_{pO_2} from 98-100%. The MRI study was repeated on the following day to define possible lower brainstem injury. The same method of ventilation was employed, again without complications.

Case 2: MRI was requested to evaluate possible brain-stem changes resulting from recent meningitis in a 3.5-year-old girl with primary pulmonary alveolar hypoventilation syndrome (Ondine's Curse) who had been ventilator-dependent since birth. A successful simulation of manual ventilation and monitoring prior to MRI was performed in the PICU as in Case 1, and the MRI was accomplished without incident.

Case 3: A 3.5-year-old girl was admitted to the PICU from the operating room where she had undergone repair of multiple, complex craniofacial deformities. Her course was uneventful except for unexplained intermittent episodes of bradycardia. An MRI was ordered to determine if a tonsillar herniation or other brain-stem involvement might be the cause of these episodes. A successful simulation of manual ventilation and monitoring was performed in the PICU as in Cases 1 and 2, and the subsequent MRI was accomplished without incident.

Discussion

The need to artificially ventilate patients during MRI may occur infrequently in some institutions, but in some patients MRI may be important for defining the pathology present. We believe that the method we have described is easy, reliable, and inexpensive.

The importance of monitoring the patient cannot be overemphasized. Standard electrocardiographic monitoring is not possible in the scanning room, and, therefore, other monitoring must be utilized.[4-6] The therapist must observe the integrity of airway connections and the degree of chest expansion. In the event of an airway disconnection, the scanner can be stopped, and the patient extracted from the scanning cylinder in a matter of seconds. The pulse oximeter should be positioned for direct observation by the therapist to ensure adequate oxygenation and heart rate. The therapist should be positioned to allow intermittent monitoring of pulse in the patient's extremities to correlate with pulse-oximeter function. The compressible volume of the extension tubing can, of course, affect the tidal volume delivered to the patient. If adequate chest expansion cannot be achieved with the pediatric resuscitator, the adult size must be used. However, we believe that the clinical reconcilation of chest motion during manual ventilation with motion during mechanical ventilation, and the assurance of stable P_{ICO_2} confirmed by blood gas analysis provides sufficient protection from possible hypoventilation in stable patients.

Although this is a simple modification that met with no objections from the manufacturer's representative and is easy to use, it must be remembered that any modification of equipment is the responsibility of the person or institution making and using that modification.

PRODUCT SOURCES

Manual Resuscitators:

#550004, Laerdal Nondisposable (infant), Laerdal Medical Corp, Armonk NY

#560004, Laerdal Disposable (pediatric), Laerdal Medical Corp, Armonk NY

#570005, Laerdal Disposable (adult), Laerdal Medical Corp, Armonk NY

Mercury CPR (disposable), Mercury Medical, Clearwater FL

Mechanical Ventilator:

Model S-171 95, Siemens Servo 900C, Siemens-Elema, Solna, Sweden

Pulse Oximeters:

N-200 (non-MRI-compatible), Nellcor Inc, Hayward CA

Model BC1 Microspan 1040A (MRI-compatible), Biochem International, Waukesha WI

Transcutaneous Carbon Dioxide Monitor:

Model 810A, Novametrix Medical Systems Inc Wallingford CT

Tubing, Connectors, and Adapters:

Oxygen tubing (No. 001301), Baxter Healthcare Corp, Valencia CA

Rubber connector (No. 172200), Marquest Medical Products, Englewood CO

15-mm ID/22-mm OD adapter (No. 172215), Baxter Healthcare Corp, Valencia CA

Large-bore disposable tubing (No. 001426), Baxter Healthcare Corp, Valencia CA

Tygon tubing, VWR Scientific, Seattle WA

ET-tube adapters, Portex, A Smith Industries Medical Systems Co, Wilmington MA

MRI-Compatible Oxygen Tank and Regulator:

Veriflo Corp, Richmond CA

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CORRECTION

An error occurred in Svedmyr's paper "Clinical Advantages of the Aerosol Route of Drug Administration" (Respir Care 1991;36:922-930). Figure 5 was incorrect; the corrected figure and its legend appear below. We regret the error.

High-dose inhaled versus intravenous salbutamol in severe acute asthma

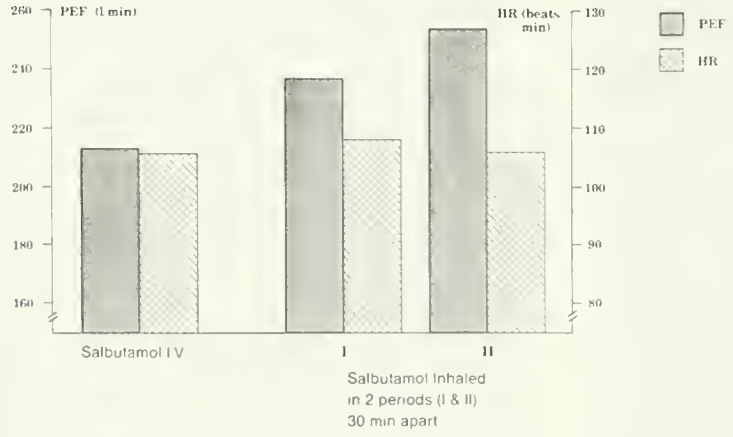

Fig. 5. Mean peak expiratory flow (PEF) values and heart rate in a parallel group study of 176 patients treated either with intravenous salbutamol (5 μg/kg) or with salbutamol (0.15 mg/kg) inhaled in two periods (I and II) 30 minutes apart. (Reprinted, with permission, from Eur Respir J 1990;3:163-170.)

Acute Effects of 'Standard' Smoke Injury to the Lung Parenchyma

Gary F Nieman BS

Introduction

Clinically important smoke inhalation is present in 21% of burn victims and plays a major role in the mortality rate (28-57%) of these patients.[1-3] In fact, respiratory tract damage is a primary cause of death in the burn victim and is a major factor complicating treatment.[4,5] Smoke-inhalation victims who enter the health-care system present a wide range of signs and symptoms, from no overt lung involvement to obvious respiratory dysfunction. Some patients with subclinical inhalation injury will progress; those patients with multiple insults (smoke inhalation, burns, trauma) and those for whom resuscitation (fluid challenge) was necessary comprise the group most likely to experience further deterioration of respiratory function.[1] In severe cases of smoke inhalation combined with cutaneous burns, mortality is high and death occurs quickly (within 10 days).[6]

Although heat may damage the upper airway (including the laryngeal region), heat is not a factor in the pathology of the pulmonary parenchyma.[7] The heat exchange capacity of the upper airway effectively dissipates the hot inhaled air, reducing it to body temperature before it reaches the lung parenchyma. The majority of deaths from fires are caused by smoke inhalation and not burns.[8]

Smoke is defined as a suspension of particulate matter in a mixture of hot gases. The upper airway usually filters out larger particles while toxic gases and smaller particles (5-10 μm) enter the small airways and alveoli.[9] Particles act as vector aerosols for aldehydes and organic acids, delivering these toxic agents deep into the lung.[10] Carbon monoxide is the most dangerous gas produced in fires,[11] and is the leading cause of death within 24 hours of the inhalation injury.[12]

Despite significant mortality and morbidity in the inhalation patient, the mechanisms for the respiratory dysfunction were unknown until recently. A major problem in the study of inhalation injury is the lack of uniformity of the smoke inhaled. The number of possible fuel sources and the variations in the amount of oxygen available for combustion can result in the generation of an almost unlimited variety of toxins. For this reason, smoke toxicology in real-fire scenarios is poorly understood, despite the fact that animal models using a so-called standard fuel source have been developed in recent years and have expanded our knowledge of smoke inhalation pathophysiology.[13] In this article, I deal with the acute effects of standard-smoke injury[14] and not with repair and healing of the lung or the long-term effects of inhalation injury. (Standard-smoke injury is the injury resulting from a 5-minute exposure at tidal breathing to the smoke generated by burning plywood sawdust moistened with kerosene.[14])

In Figure 1, the lung is represented by two alveoli connected by a respiratory bronchiole to a major airway, with a single pulmonary capillary shown in close approximation to the alveoli. Interstitial tissue lies between the alveoli and capillary. Both the alveolar epithelium and the vascular endothelium are depicted as a continuous unit to represent the normal relative impermeability of these membranes to both fluids and protein. In other words, the

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endothelium restricts fluid and protein from moving into the interstitial space (IS), and the epithelium resists fluid movement from the IS into the alveolus. Although not shown in the figure, it is assumed that a layer of pulmonary surfactant lines the surface of the alveoli. Surfactant plays a role in both lung inflation and lung-fluid balance.[15,16] Red blood cells and a neutrophil are shown flowing through the capillary, and an alveolar macrophage is seen inside the alveolus. All these structures play a role in the pathophysiology produced by smoke. (A detailed description of lung fluid-balance physiology, including the role of endothelial and epithelial permeability and alveolar surface tension, can be found in other reviews.[17,18])

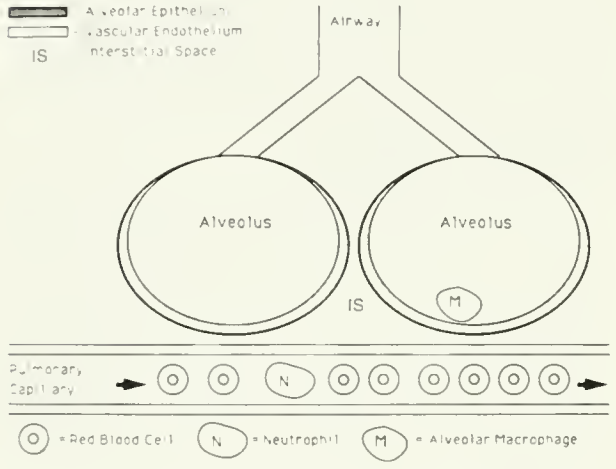

Fig. 1. The lung as represented by two alveoli, an airway, and a single capillary. The alveolar epithelium and the vascular endothelium are depicted as continuous structures to illustrate their relative impermeability to fluid and protein.[17,18]

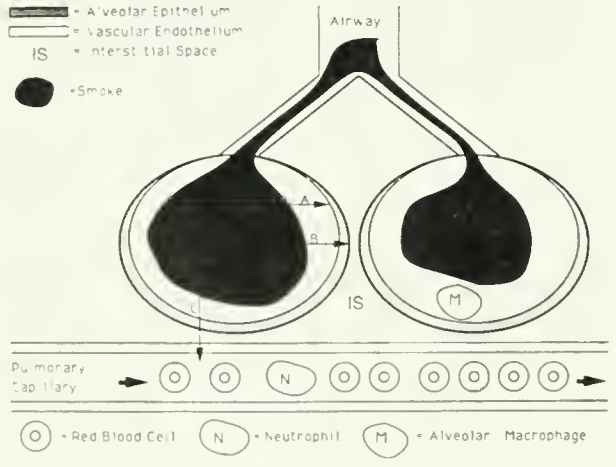

Fig. 2. Smoke initially destroys or deactivates surfactant (A), damages alveolar epithelial cells (B), and elevates carboxyhemoglobin (C).

Pathophysiologic Mechanisms

The entrance of standard smoke into the alveolus results in three primary injuries[14] (Figs. 2-4). Smoke deactivates or destroys pulmonary surfactant, which elevates alveolar surface tension (Fig. 2). High surface tension causes both alveolar collapse (resulting in pulmonary shunting[14,19]) and pulmonary edema.[16] Pulmonary damage from smoke is not uniform and can result in the development of atelectatic lung areas adjacent to fully inflated areas.[14] This nonsegmental atelectasis is probably due to uneven distribution of smoke throughout the lung. Smoke directly damages epithelial cells thereby increasing alveolar epithelial permeability (Fig. 3);[20] and carbon monoxide binds with hemoglobin in the red blood cells, significantly reducing the oxygen-carrying capacity of the blood.[19] These primary injuries begin a sequence of pathologic events that results in a lung injury similar to that found in the adult respiratory distress syndrome (ARDS).[21-23]

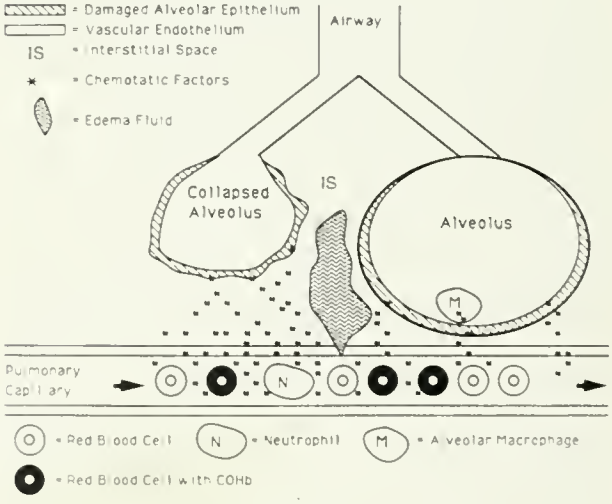

Fig. 3. Smoke produces a nonsegmental atelectasis (represented by one collapsed and one inflated alveolus) due to uneven distribution of smoke and asymmetrical damage to surfactant. Damaged epithelium releases chemotactic factors that recruit and activate neutrophils. Elevated alveolar surface tension increases transvascular fluid flux (edema fluid).[15,16,24]

Smoke-induced nonsegmental atelectasis—represented schematically as one collapsed and one inflated alveoli in Figure 3—increases pulmonary shunting (which results in hypoxemia[14,19]) and high alveolar surface tension increases lung water.[16,18] Elevated surface tension has a 'suction' effect that decreases the interstitial hydrostatic pressure thereby establishing a pressure gradient that favors fluid movement from the capillary into the interstitium.[16-18,24] A moderate amount of edema fluid is shown moving from the capillary into the interstitium (interstitial edema) in response to the elevated surface tension (Fig. 3). Smoke is known to increase alveolar epithelial permeability[20] (represented schematically by a change from the normal continuous epithelium shown in Figure 2 to a discontinuous epithelium in Figure 3.) A damaged epithelial membrane predisposes the alveolus to flooding.[18]

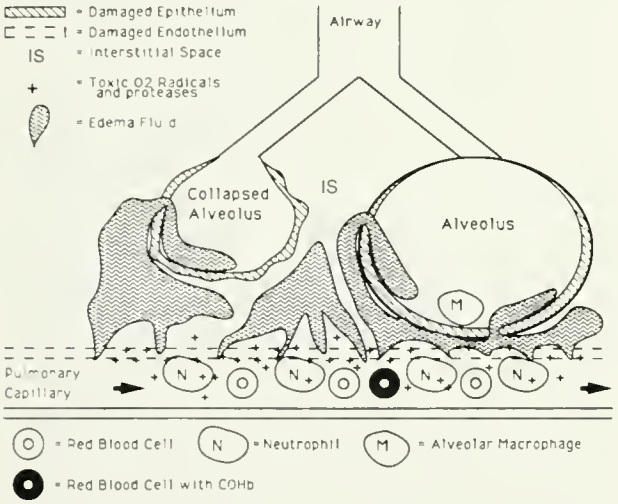

Fig. 4. Activated neutrophils accumulate in, adhere to, and damage the vascular endothelium (horizontal broken lines) by releasing toxic oxygen radicals and proteases; a high-permeability pulmonary edema results. Damaged epithelium predisposes the alveolus to flooding. The pathology at this stage of inhalation injury is similar to ARDS.[21-23]

Carbon monoxide binds with hemoglobin thereby reducing the oxygen-carrying capacity of the blood. The combination of increased shunt (atelectasis) and decreased blood oxygen-carrying capacity due to COHb results in an important decrease in oxygen delivery (Fig. 5). Although unproven, smoke-damaged epithelium and macrophages probably release chemotactic polypeptides (Fig. 3) that activate and recruit neutrophils.[25] Accumulation of activated neutrophils in the pulmonary vasculature with subsequent release of toxic oxygen radicals and proteases is believed responsible for the majority of the lung damage and pulmonary edema associated with smoke inhalation.[26-28] However, the toxic chemicals in smoke also may cause direct pulmonary damage.[10,29] My co-workers and I have demonstrated an immediate increase in pulmonary lymph flow[29] and extravascular lung water[19] following wood smoke inhalation, indicating that toxins in the smoke directly damage pulmonary endothelium. It is likely that both of the above mechanisms play a role in high-permeability pulmonary edema following smoke inhalation (Fig. 5).

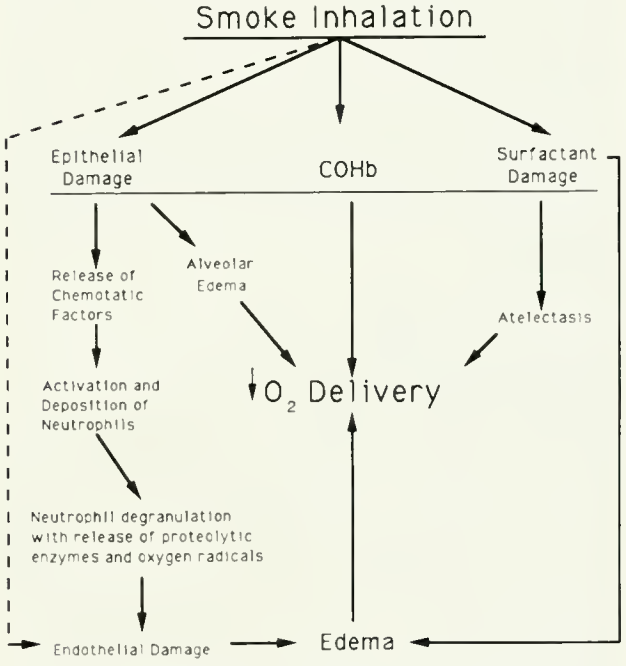

Fig. 5. Pathophysiologic sequelae of smoke inhalation on the pulmonary parenchyma—initial damage to epithelium and surfactant and elevation of COHb. Direct damage to endothelium (dotted line) may also occur. Atelectasis, high-permeability edema, hypoxemia, and decreased oxygen delivery are typical of late-stage smoke inhalation.

Traber et al[30] demonstrated a delay between insufflation of cotton smoke and increased pulmonary lymph flow and extravascular lung water. They believed that the delay between injury and pathology represented the time necessary to recruit a sufficient number of activated neutrophils to damage the pulmonary vascular endothelium.[25]

A large number of activated neutrophils have adhered to the vascular endothelium in response to release of chemotactic factors (Fig. 4). These neutrophils degranulate, releasing toxic oxygen radicals and proteases[31] that (added to direct damage from toxins in the smoke) injure the vascular endothelium and increase its permeability to both fluid and protein. A large amount of edema fluid is seen flowing through the damaged pulmonary capillary into the interstitium and eventually into the alveolus (Fig. 4). Alveolar flooding may occur swiftly (due to the increase in alveolar epithelial permeability as illustrated in Figure 4 and 6[20]), which will exacerbate the hypoxemia initially caused by the atelectasis. At this point, the pathology of the smoke-injured lung is similar to that of a lung in a patient with ARDS (ie, ARDS is characterized by severe hypoxemia and high-permeability pulmonary edema[22] with the pathogenesis including complement activation,[32] prostaglandin release,[33] and neutrophil sequestration with subsequent release of toxic oxygen radicals and elastase[21]).

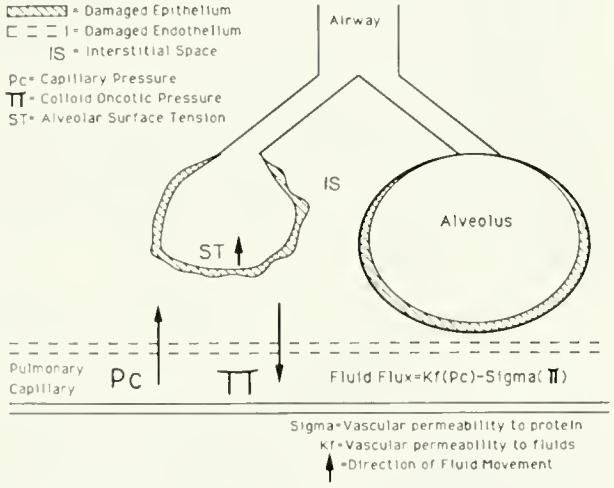

Fig. 6. Overview of physiologic forces effecting transvascular-fluid movement in the smoke-damaged lung. Smoke-injured epithelial and endothelial membranes (broken lines) allow increased transmembrane movement of both fluid (Kf) and protein (σ). Increased alveolar surface tension (ST) reduces the interstitial hydrostatic pressure increasing the transvascular pressure gradient (capillary – interstitial pressure). Crystalloid resuscitation for a concomitant surface burn decreases colloid oncotic pressure (π) and thus reduces the amount of fluid absorbed into the vessel from the interstitial space.

The physiologic forces responsible for the movement of fluid from the vasculature into the interstitium are highlighted in Figure 6. Vascular hydrostatic pressure (P_c) and colloid oncotic pressure (π) are the two major forces governing the movement of fluid across the vascular endothelium. P_c tends to move fluid out of the vasculature by hydrostatic forces and π tends to absorb fluid from the interstitium into the vasculature by osmotic forces. Alveolar surface tension exerts a force on the interstitial space; as surface tension increases, the interstitial hydrostatic pressure decreases thus increasing the pressure gradient across the vasculature. The permeability of the vasculature to both fluid (Kf) and protein (σ) also plays a critical role in transvascular fluid flux. As the permeability increases, the amount of fluid moving out of the vasculature at any given capillary pressure also increases. A detailed description of the physiology of lung fluid-balance can be found in other reviews.[18,34,35]

Understanding the forces that govern transvascular fluid flux clarifies why the smoke-injured lung is so susceptible to pulmonary edema (Table 1). Smoke damages both the vascular endothelium,[25,28-30] effecting a high-permeability pulmonary edema, and the alveolar epithelium predisposing the alveoli to flooding.[20] High alveolar surface tension causes a 'suction' effect decreasing the hydrostatic pressure in the interstitial space (Fig. 6).[15,16,20] This increases the pressure gradient across the endothelium (capillary interstitial pressure) and increases transvascular fluid flux, even if P_c does not change. However, recent studies have shown that smoke inhalation may increase P_c, greatly accelerating fluid moving through the damaged endothelium.[36] Also, recent data suggest that control of pulmonary perfusion may be impaired

Table 1. The Pathologic Consequences of Smoke Inhalation that Precipitate Pulmonary Edema

Increased vascular endothelial permeability[25,28-30]
Increased alveolar epithelial permeability[20]
Increased alveolar surface tension[15,16]
Increased pulmonary capillary hydrostatic pressure[36]
Loss of perfusion control[37]

by smoke inhalation.[37] Theoretically, blood should be shunted away (vascular derecruitment) from smoke-injured lung areas by the mechanism of hypoxic pulmonary vasoconstriction,[38] but preliminary studies indicate that blood flow actually increases to atelectatic lung areas damaged by smoke.[37] The failure to derecruit injured areas of the lung has been shown to be an important factor in the morbidity and mortality of ARDS patients.[23]

The factors described put the smoke-exposed lung at risk for developing edema, especially if large volumes of fluids are needed to resuscitate the patient with a major burn;[19] victims of smoke inhalation frequently sustain extensive burns.[39] Rapid infusion of crystalloids (saline) tend to decrease π, reducing the quantity of fluid absorbed from the interstitium and thus increasing the net volume of fluid entering the interstitial space and accelerating the rate of edema formation.[19]

Clinical Aspects of Management

The treatment of severe smoke inhalation and ARDS are similar; both treatment regimens are mostly supportive and represent response to the clinical signs rather than an attack on the underlying pathology. Smoke-inhalation injury results in atelectasis, secondary to surfactant deactivation,[14] and alveolar flooding secondary to increased permeability[20] and high surface tension.[16,24] The resultant hypoxemia is caused by intrapulmonary shunting (ie, perfusion of unventilated alveoli) with the diagnosis made by arterial blood gas analysis. Although the hypoxemia attributable to ventilation-perfusion mismatch may be corrected with supplemental oxygen, frank intrapulmonary shunting and increased alveolar dead space may require intubation and mechanical ventilation. Shunting may also respond to the addition of positive-end expiratory pressure (PEEP). These procedures may improve oxygenation, but they do not address the underlying causes of the hypoxemia (namely the increase in vascular permeability and high alveolar surface tension). Current research is exploring protocols targeted at reversing those pathologic changes.

Current Areas of Research

A number of experimental studies have demonstrated that free-oxygen-radical production associated with lung injury damages pulmonary microvascular membranes and increases vascular permeability.[40] The cellular damage caused by the toxins contained in the smoke cannot be prevented; however, the secondary injury caused by oxygen radicals and proteases is treatable. Brown et al[27] treated sheep following cotton smoke inhalation with the free-oxygen-radical scavenger dimethylsulfoxide (DMSO), and significantly reduced the severity of injury. Also, Kimura et al[41] treated animals with antiproteases following smoke inhalation and found that pulmonary damage was less severe. In various lung-injury models, several drugs that either block free-radical production or act as free-radical scavengers (ie, allopurinol, catalase, DMSO, dimethylthiourea [DMTU], deferoxamine, acetylcysteine) have been associated with decreased lung damage. These preliminary studies suggest a potential role for drugs with antiprotease and/or antioxygen-free-radical activity in the treatment of smoke inhalation.

The nonsteroidal anti-inflammatory drug, ibuprofen, has been shown to prevent the formation of pulmonary edema following smoke inhalation in rats.[42] Ibuprofen blocks the rise of the leukotriene thromboxane and increases the formation of prostacyclin. Leukotrienes are powerful vasoactive and edemagenic metabolites of arachidonic acid.[43] Conversely, prostacyclin is associated with less platelet aggregation, improved microcirculation perfusion, and decreased vascular permeability.[44,45] It is possible that ibuprofen's protective actions are independent of its effect on eicosanoids. Ibuprofen has been shown to stabilize lysosomal membranes,[46] inhibit leukocyte migration,[47] and inhibit platelet aggregation,[48] all of which would be beneficial in the treatment of smoke inhalation. On the other hand, use of steroidal anti-inflammatory drugs in the treatment of smoke inhalation has proven ineffective. In a recent study,[49] we found that methylprednisolone did not lessen the pulmonary trauma associated with our animal model of smoke inhalation. These observations are consistent with

the lack of steroid benefit in patients with inhalation injury.[50]

The studies described have focused on preventing or reducing the degree of vascular damage associated with smoke inhalation; however, re-establishing the damaged surfactant system is a second possible approach to the treatment of smoke inhalation. Our group recently began a study (funded by the American Respiratory Care Foundation) in which we attempt to replace pulmonary surfactant following smoke inhalation with aerosolized Exosurf™ (Burroughs-Wellcome Co. Research Triangle Park NC). Exosurf is a totally synthetic surfactant containing the active ingredient dipalmitoylphosphatidylcholine (DPPC). In our study, animals are anesthetized and placed on a ventilator. The aerosolized surfactant is delivered continuously with tidal ventilation for 4 hours following smoke exposure. Preliminary data suggest that aerosolized surfactant is ineffective in severe smoke inhalation (COHb $\geq$ 50-60%), but is effective in treating less severe injury (COHb $\geq$ 20-25%).

In summary, inhalation of standard smoke initially damages the alveolar epithelium, the vascular endothelium, and the pulmonary surfactant system, which sets in motion a chain of pathologic events ending with a lung injury similar to that of ARDS (Fig. 5). Smoke injures the lung in such a way as to make it highly susceptible to developing pulmonary edema (Table 1); the rate of edema formation may be accelerated if intravenous fluid is administered to treat a concomitant surface burn. Current research suggests that free-radical scavengers, antiproteases, leukotriene inhibitors, prostacyclin, and exogenous surfactant may prove effective in the treatment of smoke inhalation.

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Positive-Expiratory-Pressure Mask Therapy: Theoretical and Practical Considerations and a Review of the Literature

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Introduction

The effective removal of bronchial secretions is one of the important aspects of care in the management of patients with chronic pulmonary conditions characterized by large-volume sputum production (> 30 mL/day).[1,2] These include diseases such as cystic fibrosis (CF), chronic bronchitis (CB), and bronchiectasis. Chest physiotherapy (CPT)—encompassing postural drainage used in conjunction with percussion, vibration, and cough—represents the conventional approach to promoting secretion removal in this patient population. Although CPT may serve as a valuable bronchial hygiene therapy in some patients, it may not be the most appropriate or effective technique for all patients.[2]

Positive-expiratory-pressure (PEP) mask therapy is a bronchial hygiene technique that may serve as an effective alternative to CPT in mobilizing secretions. Developed in Denmark in the late 1970s, PEP mask therapy has gained increasing clinical acceptance in Europe and Canada over the past decade, and now (1991) represents a primary bronchial hygiene technique in many Western European countries. Additionally, some evidence suggests that PEP mask therapy is more effective than incentive spirometry and intermittent positive-pressure breathing (IPPB) in the management of postoperative atelectasis,[3,4] and as an adjunct to enhance the benefits of aerosol bronchodilator delivery.[5,6] In this overview we outline the historical development of PEP mask therapy, its theory and techniques, and its application at our institution.

PEP Mask Administration Techniques

PEP mask therapy is performed with the subject seated comfortably, with elbows resting on a table (Fig. 1). Equipment consists of a soft, transparent hand-ventilation mask, T-assembly with a one-way valve, an adjustable expiratory resistor, and a manometer (Fig. 2). The mask is applied tightly but comfortably over the mouth and nose. The subject is instructed to relax while performing diaphragmatic breathing and inspiring a volume of air larger than normal tidal volume (but not to total lung capacity) through the one-way valve. Exhalation to functional residual capacity (FRC) is active but not forced, through the fixed-orifice resistor chosen to achieve a positive expiratory pressure (PEP) from 10-20 cm H_2O [0.98-1.96 kPa] for the duration of exhalation. Most subjects achieve this pressure range utilizing flow resistors of 2.5-4.0 mm in diameter. Selection of the proper resistor also produces the desired inspiratory-to-expiratory ratio of 1:3 to 1:4. The manometer is placed in-line to measure the expiratory pressure and to serve as vis-

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Fig. 1. A 12-year-old child demonstrating proper positioning and use of PEP mask. (Reproduced with permission from the subject's parent.)

ual feedback to the subject. Once the proper resistor orifice has been determined and the technique is mastered, the manometer may be removed from the system. A series of 10-20 breaths is performed with the mask in place; the mask is then removed, and the subject performs several forced expiratory maneuvers (huff coughs) to raise secretions. This sequence of 10-20 PEP breaths, followed by huff coughing, is repeated 4-6 times per PEP therapy session. Each session takes from 10-20 minutes, and may be performed 1-4 times/day as needed. Table 1 summarizes the steps involved in a PEP therapy session.

Table 1. Steps in Performing PEP Mask Therapy

1. Assemble equipment, select appropriate expiratory resistor.
2. Sit with elbows resting comfortably on table, with mask applied tightly but comfortably over nose and mouth.
3. Use diaphragmatic breathing, take in a larger than normal breath but not to TLC. (PEP can be sucessfully performed with obtunded patients with passive, tidal ventilation.)
4. Exhale actively but not forcefully, maintaining a positive expiratory pressure of 10-20 cm H_2O. Exhalation should be about 2-3 times longer than inspiration.
5. Perform 10-20 PEP breaths, then remove mask and perform 2-3 "huff" coughs.
6. Cough to raise secretions as needed.
7. Repeat steps 2-6 several times (4-8 times) for a complete PEP session.

Huff coughing is a modified forced expiratory technique (FET) that is performed by exhaling from high to mid-lung volumes through an open glottis. The subject takes in a slow, deep breath, followed by a 1-3 second breath-hold, and then performs short, quick, forced exhalations with the glottis open. The subject may be instructed to say the word "huff" during exhalation. Small children can be taught to flap their arms to their lateral chest as they perform the huff cough, a technique referred to as the chicken breath. This activity may help the child to focus on the expiratory maneuver and associates positive reinforcement and enjoyment with the huff technique.

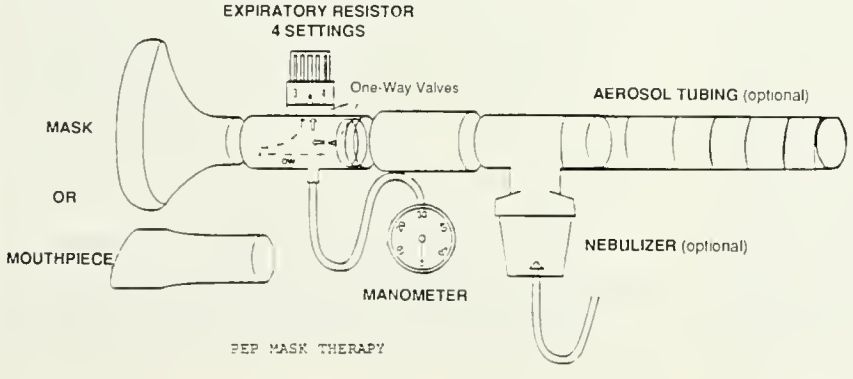

Fig. 2. Components of a PEP mask system. (Modified from Resistex™, with permission from DC Lung Co.)

The equipment used to provide PEP mask therapy can be easily assembled from available parts in any respiratory care department or may be purchased as a prefabricated system with variable orifice resistors. Typical components and commercially available systems are described in the Appendix, which follows the text.

PEP Administration Considerations

Selection of a resistor of appropriate size is critical to proper technique. The therapeutic goal of exhalation is to achieve a positive expiratory pressure from 10-20 cm H_2O, with an I:E of 1:3 to 1:4. Selection of a resistor with too large an orifice produces a short exhalation, with failure to achieve the proper expiratory pressure. Too small an orifice prolongs the expiratory phase, elevates the pressure above 20 cm H_2O, and increases the work of breathing. Performing PEP therapy for more than 20 minutes may lead to fatigue. Our experience suggests that it may be best to perform full therapy sessions in the early morning and late evening, with abbreviated sessions during the daytime as needed. During periods of exacerbation, individuals are encouraged to increase the frequency with which PEP is performed, rather than extending the length of individual sessions.

Aerosol therapy may be administered simultaneously with or just prior to a PEP session, either by hand-held nebulizer or metered dose inhaler (MDI). Based on the work of Andersen and Klausen,[5] we encourage administration of bronchodilator aerosol in conjunction with PEP for those subjects who respond to bronchodilator medication. Andersen and Klausen applied face-mask PEEP while administering nebulized bronchodilators to 8 patients with severe bronchospasm. A randomized, crossover design was used, with each patient subjected to 2 PEEP treatments and 2 control treatments with zero end-expiratory pressure (ZEEP), at intervals of 3 hours between each treatment. Forced expiratory volume in the first second FEV_1, forced vital capacity FVC, and peak flow improved significantly following PEEP treatments ($p < 0.05$). This led to the conclusion that PEEP improved the efficacy of bronchodilator administration, probably mediated through a better distribution to the peripheral airways. Our experience

Fig. 3. A 12-year-old child performing modified PEP therapy, utilizing a mouthpiece in conjunction with bronchodilator nebulizer therapy. (Reproduced with permission from the subject's parent.)

has shown that when nebulized bronchodilators (or antimicrobials) are administered in conjunction with PEP mask therapy, a mouthpiece (Fig. 3) substituted for the mask (nose clips optional) is more acceptable to some subjects who find the aerosol flow uncomfortable on their face. Alternatively, subjects may be taught to use PEP in conjunction with an MDI and spacer. A recent study by Frischnecht-Christensen et al[6] examined the effect of PEP mask applied in conjunction with beta-$_2$ agonists administered via MDI with spacer. In this randomized, crossover study, 8 patients alternately received treatments of 2 puffs of terbutaline MDI without PEP, terbutaline MDI with PEP, and placebo MDI with PEP. Results showed statistically significant improvement ($p < 0.0001$) in peak expiratory flowrate (PEFR) when terbutaline was taken in conjunction with face-mask PEP of 10-15 cm H_2O. We have successfully utilized MDI with the Resistex PEP system, which accepts a spacer device on the distal inspiratory limb of the PEP assembly (Fig. 4).

PEP mask therapy can be implemented when the patient is admitted to the hospital and is usually well tolerated by patients of all ages. However, in our experience, patients who are experiencing

Fig. 4. A PEP system with an MDI and spacer on the distal inspiratory limb.

severe dyspnea and increased work of breathing on admission often lack the concentration to perform PEP therapy initially. Therapy orders may be written for PEP instruction, followed by CPT or PEP therapy alternating on a treatment-to-treatment or daily basis, until proper performance and efficacy have been demonstrated and the acute exacerbation has passed. By Day 3 or 4 of hospitalization, CPT can often be discontinued, with most patients able to assume full responsibility for the performance of their own PEP mask therapy.

Although no absolute contraindications to the use of PEP mask therapy have been reported, common sense dictates that patients with acute sinusitis, ear infection, epistaxis, or recent facial, oral, or skull injury or surgery should be carefully evaluated before a decision is made to initiate PEP-mask therapy. Patients who are experiencing active hemoptysis or those with unresolved pneumothorax should avoid using PEP therapy until these acute pulmonary problems have resolved. While potential complications such as barotrauma or hemodynamic compromise exist with the use of positive pressure, no complications have been reported when PEP mask therapy has been used for secretion clearance, probably in large part due to the techniques involved in the therapy and the patient population.

Review of the Literature

Pursed-lips breathing is a simple procedure, which many patients with chronic obstructive lung disease have taught themselves, to relieve air trapping caused by collapse of unstable airways during expiration. It is believed that the resistance at the mouth during a pursed-lips exhalation transmits back pressure to splint the airways open (Fig. 5), preventing compression and premature closure.[7,8] As an instinctive adaptation to disease, pursed-lips breathing probably represents a functional predecessor to many of our modern strategies of applying positive expiratory pressure to the airway.

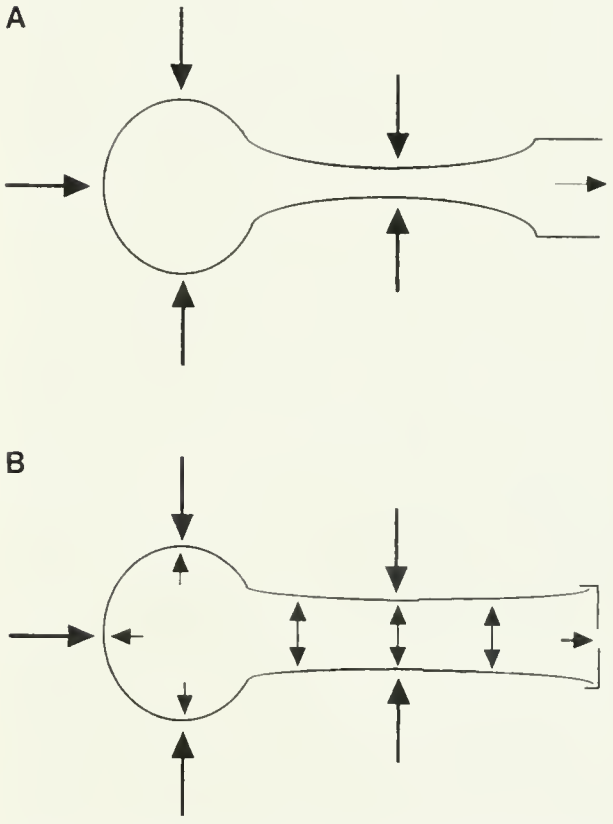

Fig. 5. A. Elevated intrathoracic pressure can compress unstable airways during exhalation. B. Pursed-lips breathing (or use of a fixed-orifice resistor such as a PEP device) creates back pressure that splints the airway open during exhalation.

In 1936, Poulton and Odon[9] described the use of the positive-pressure mask for the treatment of congestive heart failure and cardiogenic pulmonary edema. One year later, Barach et al[10] reported on the use of "continuous positive pressure breathing" (CPPB) by mask in patients suffering from respiratory obstruction and pulmonary edema. At that time, the positive pressure mask did not find application for the treatment or prophylaxis for post-

operative pulmonary complications. Thirty years later, Cheney and co-workers[11] described improvements in P_{aO_2} following the application of expiratory resistance in anesthetized patients on mechanical ventilation, and speculated that this was caused by reversing alveolar collapse. In the late 1960s, Ashbaugh and colleagues established the concept of positive end-expiratory pressure (PEEP) as a technique to improve oxygenation in acute respiratory failure and adult respiratory distress syndrome (ARDS).[12] In 1971, Gregory et al[13] reported a significant reduction in mortality when continuous positive airway pressure (CPAP) was used to treat respiratory distress syndrome of the neonate, leading to the widespread application of CPAP in the newborn population.

Further research[14-16] established that PEEP and CPAP can be effective in reducing the alveolar-arterial oxygen difference [$P_{(A-a)O_2}$], and right-to-left intrapulmonary shunt, increasing FRC in the intubated patient with acute respiratory failure (ARF) with or without mechanical ventilation. The preventive and therapeutic use of CPAP and PEEP in nonintubated patients, however, did not receive much attention until the early 1980s. The reader is referred to the comprehensive reviews by Branson previously published in this journal on mask CPAP[17] and PEEP in the non-intubated patient.[18]

In 1980, Andersen et al[19] conducted a prospective, randomized, controlled clinical trial using a sequential-analysis design to determine the effect of conventional therapy versus conventional therapy plus periodic CPAP by mask, in the treatment of 24 surgical patients with atelectasis. CPAP was given each hour for 25-35 breaths with a pressure averaging 15 cm H_2O [1.47 kPa]. At 12 hours, patients in the CPAP group exhibited significantly greater improvement (P_{aO_2} and radiographic findings) as compared to the control group. This study prompted Pontoppidan to consider periodic CPAP as a tool for treatment of postoperative pulmonary complications.[20] Several studies during the early 1980s explored the application of PEEP and CPAP to nonintubated patients in different fashions with varying results,[3,21-26] including comparisons of mask CPAP to incentive spirometry, deep breathing and coughing (DBC), and IPPB. As more effective strategies were developed, Stock et al[25,26] concluded that intermittent mask CPAP was as effective as incentive spirometry or deep breathing and coughing in return of pulmonary function following thoracic or upper-abdominal surgery. Additionally, the authors suggested that mask CPAP might be preferable, as it represented a more effortless, painless type of postoperative respiratory care.

Ricksten et al[4] performed a randomized comparative study of 43 upper-abdominal-surgery patients that looked at postoperative complications, $P_{(A-a)O_2}$, PEF, and FVC in patients using either CPAP or PEP against a control group using incentive spirometry. All 3 groups took 30 breaths each hour while awake, for 3 days postoperatively. Although peak flow did not change between groups, FVC was greater in the CPAP and PEP groups. $P_{(A-a)O_2}$ increased uniformly for all groups for the first 24 hours, but then decreased in the CPAP and PEP groups (being insignificantly lower in the PEP group). Atelectatic consolidation was observed in 6/15 patients in the control group, 1/13 in the CPAP group, and 0/15 in the PEP group. The authors concluded that periodic PEP and CPAP are superior to deep breathing exercises with respect to gas exchange, preservation of lung volumes, and prevention of postoperative atelectasis following upper-abdominal surgery. They also concluded that "the simple and commercially available PEP mask is as effective as the more complicated CPAP system." A simple PEP system as described earlier certainly represents a cost savings over the use of a more complex CPAP system, which requires a gas flow, pressure monitor, and oxygen analyzer.

Lindner, and colleagues,[27] in a randomized study of 34 upper-abdominal-surgery patients, compared postoperative physiotherapy with postoperative physiotherapy plus mask CPAP. Their findings indicated that the group treated with physiotherapy plus CPAP had a more rapid recovery of pulmonary function (vital capacity and FRC) and fewer pulmonary complications. Campbell et al[28] randomized 71 abdominal surgery patients into two groups; Group 1 received chest physiotherapy (breathing exercises and huff coughing) and Group 2 received chest physiotherapy plus PEP. No differences were seen in FEV_1 or FVC postoperatively between the two groups, and the incidence of respiratory complications was 31% in Group 1 and 22% in Group 2, not statistically significant. The authors concluded that PEP could serve as an

adjunct to routine chest physiotherapy, particularlywith postoperative smokers because 43% of the 44 smokers in their study developed respiratory complications, compared to none of the nonsmokers ($p < 0.01$). It should be noted that their study utilized a PEP system consisting of a tube placed underwater and adjusted to produce pressures of 5-15 cm H_2O with the patient exhaling through a mouthpiece. Frolund and Madsen[29] compared chest physiotherapy (ambulation, coughing, diaphragmatic breathing, and deep breathing exercises) with chest physiotherapy plus PEP mask in a series of 56 patients who had undergone thoracic surgery. Thirteen patients in the PEP group developed atelec-tasis compared to 8 in the chest physiotherapy group ($p < 0.05$). The PEP group also had a slightly lower mean P_{aO_2}, not statistically significant. The authors concluded that postoperative PEP offered no additional benefit compared to the performance of chest physiotherapy in this patient population.

PEP therapy as a specific bronchial hygiene technique evolved from concepts first described in 1979 by Andersen et al,[30] who showed that reinflation of collapsed excised human lungs could be accomplished with CPAP by mechanisms involving collateral ventilation. Although the authors were primarily evaluating CPAP as a lung expansion technique, they noted that CPAP "has a potential secretion clearing effect in that pressure is built distal to an obstruction." The following year Andersen and Jespersen[31] made castings of human lungs, identified communications between intersegmental respiratory bronchioles, and concluded that collateral ventilation might be of importance in normal lung function. By preventing expiratory collapse, PEP is thought to facilitate a more homogenous distribution of ventilation throughout the lung, via these collateral interbronchiolar channels.

The role of PEP therapy in the mobilization of secretions was explored in a 1984 study by Falk et al[32] in which the acute effects of 4 different regimens were examined using a randomized, crossover design in 14 patients with cystic fibrosis. Treatment A consisted of postural drainage, percussion, and vibration: Treatment B of postural drainage and periodic application of face-mask PEP: Treatment C of PEP with the patient in sitting position; and Treatment D of the forced expiratory technique (FET) in the sitting position. In terms of sputum produced, Treatments B and C were superior to Treatment D and especially Treatment A ($p < 0.05$). A substantial and prolonged decay in transcutaneous P_{O_2} (P_{tcO_2}) was observed during Treatment A; whereas, during and following Treatment C, P_{tcO_2} increased. PEP therapy was reported to be well accepted by the patients, who consistently preferred Treatment C. In a companion article in the same journal, Tonnesen and Stovring[33] compared PEP mask therapy with CPT in 12 CF patients. Over the course of 6-9 months of therapy, residual volume ($p < 0.02$) and FRC were reduced, vital capacity was increased, and subjective sputum production was reported as greater in the PEP group.

Groth and associates[34] measured several lung function variables from the expiratory port of the PEP mask in 12 CF patients. During PEP mask therapy they found a significant increase in FRC ($p < 0.02$), decrease in volume of trapped gas ($p < 0.05$), and decrease of washout volume ($p < 0.05$), as compared to pretreatment measurements. The authors concluded that the changes seen during PEP mask therapy could be attributed to a more uniform distribution of ventilation within the lung and the opening up of airways otherwise closed off during normal ventilation. They also felt that "an additional effect of PEP treatment may be to get more air behind intraluminar secretions, ... (which) may then be cleared more easily by forced exhalation ...."

During this same time period, several groups[35-37] demonstrated that postural drainage with FET was superior to postural drainage alone, and that FET was a key factor (having greater effect than percussion and vibration) in mobilization of sputum. One of these groups, Hofmeyr and colleagues,[37] studied 18 CF patients, comparing FET with postural drainage, FET plus PEP with postural drainage, and FET plus PEP in the sitting position. FET with postural drainage produced more sputum than either of the two other regimens that included PEP ($p < 0.025$ and $p < 0.001$, respectively). They concluded that the addition of PEP to the treatment regimen was not valuable. Tyrrell et al[38] compared PEP mask in conjunction with forced expiratory coughing to conventional physiotherapy for 1 month in 16 CF patients. Although no difference was seen in symptom scores, sputum production, or

simple lung tests between the two techniques, the authors found that PEP mask therapy was well accepted by older patients, allowing for a greater sense of independence as compared to CPT.

Oberwaldner et al[39] studied 20 CF patients who had previously used conventional CPT and were taught PEP therapy. After PEP training, each patient exceeded his previous FVC once the optimum resistor setting had been established. During PEP therapy, patients cleared a higher percentage of their daily sputum volume than with conventional CPT (78 vs 53%, $p < 0.01$). Eleven of the patients received 10 months of PEP therapy, 2 months of conventional physiotherapy, and another 4 months with PEP. Results showed significantly less hyperinflation and airway instability with PEP therapy and a marked decline of lung function without it.

Van Asperen et al[40] compared PEP to postural drainage (PD) with percussion in 10 CF patients in a randomized, crossover design that consisted of initial evaluation by a physiotherapist and a diary kept over a short-term, 4-week treatment period. PEP therapy failed to produce any significant difference in sputum production, symptom scores, or peak expiratory flow, as compared to PD with percussion. The authors concluded that PEP mask therapy represented an acceptable alternative to PD with percussion, although it offered no advantage other than convenience. Another study by Kaminska and Pearson reached similar conclusions.[41] They alternated daily use of postural drainage with FET and PEP mask therapy, for 6 weeks in 12 patients with bronchiectasis. While one or more subjects showed improvement in PEFR or sputum production when comparing the two techniques, little difference in total sputum production or PEFR was seen between the two groups. They concluded that a minority of patients benefited from PEP, but that PEP did not offer added advantages for patients who can perform PD with FET and should not be considered more than a useful adjunct, valuable more for its convenience and time savings than for its therapeutic advantage.

Autogenic drainage (AD) is a secretion-clearance technique that combines variable tidal breathing at three distinct lung volume levels, controlled expiratory airflow, and huff coughing. Davidson et al[42] compared PEP therapy, autogenic drainage, and postural drainage and percussion in 18 CF patients in a randomized, crossover design. Each patient performed each of the 3 techniques for 2 months. The researchers concluded that although FVC, FEV_1/FVC, and $FEF_{25-75\%}$ did not change between groups, a significant increase in sputum production was seen with AD over PEP and PEP over PD ($p < 0.01$).

van Hengstum et al,[43] in a randomized, crossover trial of 8 patients with chronic bronchitis, compared the effects of PEP versus postural drainage with FET on tracheobronchial clearance of a radioaerosol. Forty minutes after the start of therapy, clearance was expressed as a percent of the radiation present at the beginning of therapy. Fifty-three percent was cleared after PD with FET, 32% was cleared after PEP, and 15% during the control run. Although radioaerosol clearance with both PEP and FET was greater than the control run ($p < 0.02$), FET was found to be more effective than PEP in enhancing tracheobronchial clearance.

In a recent controlled study, Christensen et al[44] looked at 43 patients with chronic bronchitis over 12 months, comparing PEP (20 patients) to conventional CPT (control group, 23 patients). A twice-weekly patient diary of symptoms indicated that the PEP group had less cough and less mucus production. Acute exacerbations were calculated from the diaries, with 85% of the PEP group free from acute exacerbations versus 48% in the control group ($p < 0.0005$). The PEP group also used significantly fewer antibiotics and mucolytics ($p < 0.05$). The PEP group had a small increase in mean FEV_1 of 62 mL compared to a mean decrease of 43 mL for the control group. The change was not statistically significant. The authors concluded that prolonged treatment with PEP can reduce morbidity in patients with chronic bronchitis and may preserve lung function from a more rapid decline.

Two recent studies (1991) also evaluated the use of PEP mask therapy in CF patients. Steen et al[45] in a randomized, crossover trial in 24 patients, compared 4 treatment regimens, each lasting 1 month. Treatment A consisted of postural drainage, percussion and FET; Treatment B of 5 minutes of PEP mask followed by postural drainage, percussion, and FET; Treatment C of PEP mask therapy alone; and Treatment D of PEP and FET. There were no statistically significant differences between the

groups in Shwachman score, Chrispin-Norman score, expectorated sputum weight, PEFR, FEV, or FVC. The authors reported that patients enjoyed the increased independence that PEP mask therapy and FET allowed, and 23/24 patients adopted PEP mask with FET as their long-term chest physiotherapy program following completion of the study. Oberwaldner et al[46] evaluated 18 CF patients hospitalized for pulmonary exacerbation, in whom self-administered PEP mask therapy was designated as their chest physiotherapy technique. Lung function measurements were done on Days 1, 5, 10, and 15 of hospitalization, before and after the morning PEP treatment. Results indicated that there was a statistically significant improvement in multiple lung function indices in this group of patients throughout their hospitalization, the magnitude of which correlated directly with the volume of sputum produced. The authors concluded that PEP mask therapy produced short-term benefits in the hospitalized CF patient.

Table 2 summarizes the literature regarding PEP mask therapy as a secretion-clearance technique. While the evidence supporting PEP mask therapy may not be definitive, it is certainly encouraging, with further studies required to determine not only its usefulness as a bronchial hygiene technique, but also its value in long-term maintenance therapy for CF and chronic bronchitis patients, and its potential for altering dyspnea perception for patients with asthma and COPD.[47]

Discussion

PEP therapy represents an alternative technique for the mobilization of bronchial secretions, without the attendant risks or limitations associated with CPT. Deterioration in pulmonary function and gas exchange have both been associated with the positional changes that accompany postural drainage.[48] Osteoarthritis, surgical incisions, and thoracic cage tenderness limit the applicability of percussion and vibration in some patients. Although an effective cough is critical for secretion clearance, uncontrolled cough can precipitate dynamic airway collapse, bronchospasm, or syncope in susceptible patients. These factors influence the effective use of CPT for a number of hospitalized individuals in need of regular bronchial hygiene therapy. Additionally, factors such as meals, scheduled diagnostic tests, sleep needs, and staff availability make it difficult to comply with orders for CPT 3 or 4 times each day. An additional concern with CPT has to do with its potential contribution to the development of carpal tunnel syndrome in health-care workers who perform percussion and vibration with multiple patients on a daily basis.[49,50]

In the home, CPT often requires the assistance of a second person, must be scheduled around meals and other events of the day, and requires an environment of relative privacy. Special equipment such as vibrators, percussors, or tilt tables are required by some subjects. The personal and professional demands on adults with CF limit the ease with which they can integrate CPT into their daily routine of independent living. Emotional and psychological issues such as disease denial or anxiety concerning body image may also influence a person's acceptance of CPT as a part of daily care. Such factors may limit compliance and reduce the effectiveness of CPT for many individuals who require daily secretion-clearance therapy, which may in turn contribute to more frequent hospitalizations for pulmonary exacerbations.

We believe that PEP therapy possesses few of the limitations associated with CPT, and we have found that PEP therapy can be easily taught to most hospitalized patients in two 30-minute sessions. Once such patients are stable, they assume responsibility for self-care for the duration of their hospitalization. Hospitalized patients who learn to self-administer PEP can reduce health-care costs related to the administration of CPT by professional hospital staff. With a typical CF patient hospitalized for 2 weeks, CPT 4 times daily for 30-60 minutes/treatment represents a total time commitment of 28-56 hours/hospitalization. Alternatively, self-administration of PEP therapy for the duration of hospitalization can dramatically reduce both institutional and patient costs, in a time when health-care-provider resources are scarce. Table 3 illustrates the potential cost savings associated with in-hospital self-administration of PEP therapy as compared to therapist-administered CPT. More importantly, these in-patients are then prepared to self-administer a more acceptable, convenient secretion-clearance technique following discharge, potentially enhancing at-home compliance with bronchial hygiene care.

Table 2. PEP Mask Therapy as a Secretion Clearance Technique—A Review of the Literature

Investigators	Patients (n/diagnosis)	Comparison	Study Design	Values Compared	Length of Study	Results
Falk et al[37] (1984)	14/cystic fibrosis	CPT (A) CPT & PEP (B) PEP (C) FET (D)	Randomized, crossover	$PtcO_2$ Sputum production	2 days	$P_{tc}O_2$ improved ($p < 0.01$) Sputum production increased over CPT alone B, C, D ($p < 0.01$)
Tonnesson & Stovring[33] (1984)	12/cystic fibrosis	CPT PEP	Controlled trial, comparison to CPT	Sputum culture Sputum production PFT	6-9 mo	Sputum production > w/PEP ($p < 0.005$) RV reduced with PEP ($p < 0.02$)
Groth et al[34] (1985)	12/cystic fibrosis	PEP, before and after	Patient as own control	PFT, FRC, TLC Wash-out volume (WOV) Volume of trapped gas Lung Clearance Index (WOV/FRC)	1 day	During PEP, FRC increased ($p < 0.02$), WOV decreased ($p < 0.05$) Lung Clearance Index decreased ($p < 0.001$) TLC, VC, RV, V_T — no significant difference
Tyrrell et al[38] (1986)	16/cystic fibrosis	CPT PEP FET	Randomized, crossover	Symptom score Sputum production PFT	1 mo	No significant difference
Hofmeyr et al[3] (1986)	18/cystic fibrosis	CPT & FET (A) CPT, FET, & PEP (B) PEP & FET (C)	Randomized, crossover	Sputum production S_aO_2 FVC, FEV_1	3 days	Sputum production A > B ($p < 0.025$) A > C ($p < 0.001$) B > C ($p < 0.005$) S_aO_2, FEV_1, FVC — no significant difference
Oberwaldner et al[39] (1986)	20/cystic fibrosis	CPT PEP	Randomized, crossover	Sputum production	16 mo	Sputum production increased with PEP ($p < 0.01$)
Van Asperen et al[40] (1987)	10/cystic fibrosis	CPT PEP	Randomized, crossover	Sputum production PFT	4 weeks	No significant difference
Kaminska & Pearson[41] (1988)	12/bronchiectasis	CPT & FET PEP	Randomized, crossover	PFT Sputum production Assess of "well being"	6 weeks	No significant difference
Davidson et al[42] (1988)	18/cystic fibrosis	CPT Autogenic drainage (AD) PEP	Randomized, crossover	PFT Sputum production	6 mo	Sputum production AD > PD ($p < 0.02$) Subjective preference — AD & PEP over CPT PFT — no significant difference
van Hengstum et al[43] (1988)	8/chronic bronchitis	CPT & FET PEP Control	Randomized, crossover	Radioaerosol clearance Sputum production	4 days	Both FET and PEP > control ($p < 0.02$) FET > PEP
Christensen et al[44] (1990)	8/chronic bronchitis	CPT PEP	Randomized trial	PFT, Sputum production Acute exacerbation Use of antibiotics and mucolytics	12 mo	Acute exacerbations decreased ($p < 0.0005$) Antibiotic/mucolytic use decreased ($p < 0.05$) FEV_1/FVC — no significant difference
Oberwaldner et al[16] (1991)	18/cystic fibrosis	PEP, before and after	Previous CPT as control	Sputum production PFT, RV, TLC Isovol-$\dot{V}_{25}$ & $\dot{V}_{50}$	15 days	Correlation of sputum production to PEP-induced lung function changes Δ FVC ($p < 0.001$), ΔFEV_1 ($p < 0.02$), ΔFEV_1/FVC ($p < 0.01$), Δ RV/TLC ($p < 0.01$)
Steen et al[45] (1991)	28/cystic fibrosis	CPT & FET (A) PEP & CPT (B) PEP (C) PEP & FET (D)	Randomized, crossover	Sputum production PFT	4 mo	No significant difference After the study, 23/24 patients chose PEP & FET as their long-term chest physiotherapy programme

Table 3. Cost Comparison between Postural Drainage and PEP Mask Therapy for 14-Day Hospital Stay for CF Patient

Procedure	Time	FTE	Hospital Costs	Patient Charge	Reimbursement	Net Gain
PDT	(4 × daily) 56 h	0.7	$1,400.00*	$5,376.00	$1,612.80	$212.80
PEP	5 h (4 × daily)	0.65 h	$125.00	$480.00	$144.00	$19.00

* Assumes salary of $20.00/h plus 25% benefits. Respiratory Care Services charges $96.00/h direct patient care, with an overall reimbursement rate of $0.30 for each hospital dollar billed.

In the community setting, subjects can conveniently perform PEP therapy in almost any environment, without requiring the assistance of a second person. Therapy sessions typically take one half to one third the time required for a conventional CPT session, raising equivalent quantities of sputum. These factors have the potential for increasing what has been reported as otherwise poor at-home compliance with bronchial hygiene techniques,[51] representing a valuable tool for preventive medicine. Utilization of an inexpensive PEP system has monthly replacement costs of less than $10.00.

Experience in Our Institution

Since 1989, PEP therapy has been taught to more than 200 subjects at the University of California Medical Center at San Francisco and throughout the San Francisco Bay area. This population includes patients with cystic fibrosis, bronchiectasis, chronic bronchitis, and bronchiolitis obliterans. PEP therapy is particularly applicable in the pediatric population in which CPT is poorly tolerated or the child is too young to master the techniques of autogenic drainage. In a recent abstract [52] we reported a series of 10 pediatric patients ranging in age from 3½ to 14 years. Nine of 10 patients who were taught PEP therapy continued to use the technique at home at 6-month follow-up, with 7/9 using PEP exclusively. Parents described the convenience associated with PEP therapy, as compared to CPT, and the relative ease with which the child self-administered treatment. Based upon our initial experience with PEP mask therapy, we continue to teach subjects this bronchial hygiene technique.

In Conclusion

We believe that PEP mask therapy can play an important role in the management of a variety of patients with cardiopulmonary disease. We have been particularly impressed with our observation that end-stage CF patients are better able to tolerate PEP therapy than either CPT or AD, both of which can exacerbate dyspnea. Factors such as decreased time commitment, convenience, comfort, lack of risks, and financial savings make PEP therapy an attractive alternative to conventional CPT, IPPB, and incentive spirometry. Although our experience is limited to the application of PEP therapy for secretion mobilization, the literature also supports the role that PEP therapy can play in the prevention and treatment of postoperative atelectasis. Several hospitals in the San Francisco Bay area have begun to incorporate PEP therapy in their management of the postoperative patient. We are currently engaged in research identifying how best to teach and perform PEP mask therapy for secretion clearance, and its role compared to that of autogenic drainage and CPT. We encourage other institutions to engage in studies aimed at further defining the roles and limitations of PEP mask therapy, AD, FET, and CPT. Our goal is to match the most appropriate therapy to the needs of the individual patient.

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Appendix

Commercially Available Devices Used for PEP

Resistex™ Expiratory Resistance Exerciser, # 370
DC Lung Company (Sebastapol CA)

Contents: One-way valve assembly with manometer port and rotating selector cap with 4 fixed orifices
Mouthpiece
Adapters for Nebulizer, MDI — Approximate Cost: $ 9.00

CPT Mask for PEP Therapy (previously PEP-em), # 9000 PEP
Vital Signs (Totowa NJ)

Contents: CPAP Mask, #9000
3 Preset PEEP valves (10, 15, 20 cm H_2O) — Approximate Cost: $25.00

The Ambu® PEP Mask System, # 250 001 000
Ambu Inc (Hanover MD)
Contents: One-way valve assembly with manometer port
8 resistance caps with fixed orifice
(1.5-5.0 mm in .5-mm increments)
Transparent mask
Zipper bag
Manometer (optional) — Approximate Cost: $40.00
(pricing pending FDA approval)

Astra Meditec PEP Mask System (available in Europe but not the U.S.)
Astra Meditec (Molndal, Sweden) — Not Available

Contents: One-way valve assembly with manometer port
Eight resistance adaptors with fixed orifice

'Home Made' PEP-Mask System

(representative configurations from parts on our respiratory-care-service shelves)

Part Description with Examples	Approximate Cost :
One-way valve assembly with manometer port	
Nif-Tee Nonrebreathing T-Piece, DHD-33-3500, DHD (Canasta NY)	$ 2.00
Connector, 22 x 15 mm	
Airlife #1820, Baxter (Deerfield IL)	$ .50
Connector, 22 x 22 mm	
Airlife #1821, Baxter (Deerfield IL)	$ .50
Face mask, transparent with cushion	
Vital Signs #1520, Vital Signs (Totowa NJ)	$ 3.50
Fixed-orifice resistors, Trach Adaptors—2.5, 3, 3.5, 4, 4.5, 5.0 mm	
Bivona Inc (Gary IN)	$ 3.00
	System Total $9.50

Fixed-Orifice Resistor Alternatives:

PEEP-FLO, Adjustable from 0-20 cm H_2O, LDS #8870
Life Design Systems (Carrollton TX) — $ 9.00

PEEP Valve with Adapter, (Preset values 10, 12.5, 15, 20 cm H_2O), VS#9007-10
Vital Signs (Totowa NJ) — $ 7.00

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PFT Corner #42— Reversible Restrictive Lung Disease?

Jack Wanger MBA RRT RPFT, Charles Irvin PhD, and Gregory A Underwood MD

A 19-year-old white woman with a life-long history of asthma was admitted to the hospital because of her worsening condition. She had been intubated 6 times in the past, with 3 of those intubations occurring in the 6 months preceding the current admission. She had also experienced numerous episodes of syncope secondary to atrial tachycardia and had undergone His-bundle ablation with pacemaker placement 10 months prior to the current admission.

Her daily medications on admission included sustained release theophylline (900 mg), methylprednisolone (40 mg), cromolyn sodium, troleandomycin (750 mg), digoxin, verapamil, and inhaled beta agonists. Physical examination revealed a Cushingoid woman with clear breath sounds. Her weight was 140 lb, and her height was 63 in. Her posteroanterior and lateral chest radiographs suggested slightly reduced lung volume and mild bronchial-wall thickening in both lungs, consistent with mild airway disease (Figs. 1 A & B). High-resolution thoracic computed tomography revealed no areas of increased interstitial markings. Results of pulmonary function tests are shown in Figure 2 and Table 1.[1-4]

Mr Wanger is Manager and Technical Director and Dr Irvin is Associate Director of the Pulmonary Physiology Unit, and Dr Underwood is an Assistant Professor in the Department of Medicine—National Jewish Center for Immunology and Respiratory Medicine, Denver, Colorado.

Questions

1. How do you interpret these pulmonary function tests?

Fig. 1A. Posteroanterior chest radiograph of 19-year-old woman admitted for evaluation of asthma.

Table 1. Results of Pulmonary Function Testing in a 19-Year-Old Woman before and after Albuterol

Tests	Before	After
TLC (L)	2.85 (59)*	3.59
TGV (L)	1.32 (51)	1.38
RV (L)	0.89 (81)	0.65
FVC (L)	1.88 (50)	2.30
FEV_1 (L)	1.82 (53)	2.15
FEV_1/FVC (%)	97	93
D_{LCO} (mL · torr · min^{-1})	25.50 (79)	—
$D_{LCO}V_A$	8.32 (122)	—
P_{Imax} (cm H_2O)	73 (91-149)†	—
P_{Emax} (cm H_2O)	59 (107-171)†	—

* Numbers in parentheses are percent of predicted.[1-3]
† Numbers in parentheses are the range of predicted values.[4]

Fig. 1B. Lateral chest radiograph of 19-year-old woman admitted for evaluation of asthma.

2. What would explain the change in lung volumes after bronchodilator?
3. What other tests do you recommend?

Answers and Discussion on Next Page

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Answers

1. PFT Interpretation: The pulmonary function studies demonstrate reduced lung volumes consistent with the radiographs (Fig. 1) and airflow limitation, which was improved after bronchodilator (Fig. 2). The diffusing capacity is at the lower limits of normal, but normal when corrected for lung volume (D_{LCO}/V_A). Maximal inspiratory and expiratory pressures are low, due either to poor effort or muscle weakness. Inspiratory flow-rates are normal.

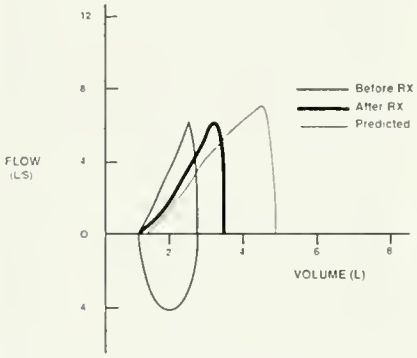

Fig. 2. Forced expiratory flow-volume curves, showing predicted curve and curves obtained before and after bronchodilator.

2. Explanation: Thoracic gas volume (at FRC) measured by body plethysmograph remained unchanged following bronchodilator (Table 1). However, the total lung capacity (TLC) markedly increased (2.85 to 3.59 L) and the residual volume (RV) fell slightly (0.89 to 0.65 L), hence the increase in vital capacity (VC). This rise in TLC is unusual because an improvement in hyperinflation (fall in lung volume) is the change usually seen following beta-agonist inhalation. Although the possibility of technical error exists, it was ruled out because of the reproducibility of the data on that day, a subsequent test (Table 2), and laboratory quality-control data. Additionally, because the reproducibility of the TLC measurements before and after bronchodilator was good, we believe that the patient was exerting maximal effort. However, the respiratory muscles might be weak (low P_{Imax} and P_{Emax}), which might explain the lower before-bronchodilator lung-volume data. However, it seems unlikely that the muscle force would improve so markedly after the single treatment with a beta agonist. At the time, we believed that the patient tried harder after bronchodilator (training effect?) and thus was able to take deeper breaths. In order for lung volumes to increase spontaneously, the respiratory muscles or the phrenic nerve would have had to respond to the bronchodilator—neither seems likely.

Table 2. Results of Follow-Up Pulmonary Function and Pressure-Volume Measurements before and after Albuterol

Tests	Before	After
TLC (L)	3.62 (75)*	4.60
TGV (L)	1.38 (54)	1.43
RV (L)	1.24 (112)	1.41
FVC (L)	1.72 (46)	3.24
FEV_1 (L)	1.56 (45)	2.94
FEV_1/FVC (%)	90	90
P_{Imax} (cm H_2O)	30 (91-149)†	
P_{Emax} (cm H_2O)	45 (107-171)†	
Coefficient of Retraction (cm H_2O/L)	15.5 (4-8)†	5.8
R_{aw} (cm $H_2O \cdot s \cdot L^{-1}$)	10.0 (< 1.5)†	2.0

* Numbers in parentheses are percent of predicted.[1,2]
† Numbers in parentheses are the range of predicted values.[1,4]

3. Additional Testing: Test results (Table 1 & Fig. 2) suggest the presence of a restrictive process, and the radiographs (Fig. 1) also suggests reduction in lung volumes. Although these changes could be due to muscle weakness or patient weight, the severe asthma should have resulted in increased lung volumes. A pressure-volume study could assess the relative contribution of muscle strength, elastic recoil, and airway narrowing to these results. A pressure-volume study was performed, and the results are shown in Figures 3 and 4, and Table 2. The results of the testing study was performed, and the results

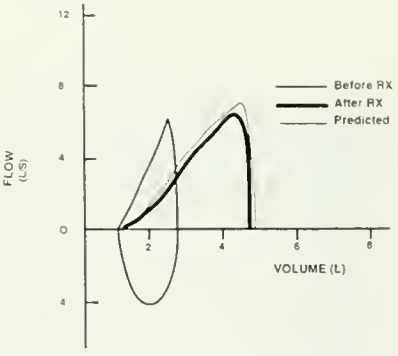

Fig. 3. Forced expiratory flow-volume curves obtained with pressure-volume study, showing predicted curve and curves obtained before and after bronchodilator.

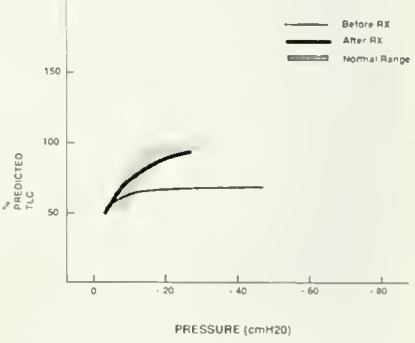

Fig. 4. Pressure-volume curves obtained before and after bronchodilator administration. Transpulmonary pressure in cm H_2O is plotted against % of predicted total lung capacity (TLC). The stippled area, or normal envelope, defines normal values.

show marked changes in lung volumes and in airflow limitation (FEV_1) after bronchodilator. The pressure-volume characteristics (PV curve) demonstrated by this patient (Fig. 4) are remarkable. Before the bronchodilator treatment, the patient had a PV curve that appeared definitely restrictive. The coefficient of retraction (COR), a numerical measure of pressure-volume characteristics, is calculated as the elastic recoil at TLC (in cm H_2O) divided by the TLC (in L). A value of 15.5 cm H_2O/L is high (normal range 4-8 cm H_2O/L)[5] and is indicative of a restrictive process. However, unlike a 'garden variety' restrictive process, this patient showed a phenomenal fall in the COR into the normal range after bronchodilator. The upstream resistance (R_{us}) is a calculation of resistance of the upstream segment (those airways upstream or towards the alveoli from the point of airway narrowing or collapse). Note that the R_{us} (Table 2) was elevated before and fell after bronchodilator, indicating airflow limitation and reversibility with bronchodilator.

Discussion

These pulmonary function tests (Tables 1 & 2 & Fig. 2) indicate that there is not only an improvement in airflow after bronchodilator administration but also an improvement in the reduced lung volumes. (The increase in FVC could be attributed to increased effort.) We believe that this patient has a reversible restrictive lung disease. Other cases of such a phenomenon have been reported, describing patients in whom the lung volumes are decreased during episodes of bronchospasm but in whom the FEV_1/FVC is preserved.[6,7]

In addition, the response of our patient resembles only in part the changes that have been reported when chest straps applied to the thorax are removed. In the study by Sybrecht and co-workers,[8] the application of chest straps resulted in a reduction in TLC of 28% (similar to our patient), did not increase recoil at TLC (coefficient of retraction), and only slightly increased R_{us} from 1.4 to 2.0 cm H_2O s L^{-1}. Thus, the changes seen in our patient can be explained only in part by the effect of chest-wall characteristics on respiratory muscle function.

Two other possible explanations need to be considered. As one exhales to RV, the supported peripheral airways narrow or close. Such changes could account for the changes in RV noted in this and other patients.[9-11] However a more plausible explanation may be an abnormality of the smooth muscle present around the alveolar ducts.[7,10,11]

At the beginning of a forced expiration, maximal expiratory flow (MEF) depends on the rapidity of contraction of expiratory muscles, elastic recoil pressure, and caliber of the airways. During the later portion of the forced expiratory maneuver, MEF is thought to be less dependent on effort and more related to elastic recoil pressure, upstream resistance, and the equal-pressure point (the point at which pleural and intrabronchial pressure are equal). If after bronchodilator administration, MEF increases and the upstream resistance to airflow decreases, it follows that the change in pressure-volume characteristics is due to an increase of constriction of the smooth muscle of the alveolar ducts. It also follows that the reversal of constriction in these peripheral lung units leads to a reversal in decreased lung volumes. What makes this patient unusual is the magnitude of response. One can only conclude that there is a marked abnormality either in function or amount of smooth muscle present in these peripheral airways that also contributes to the elastic properties of the lung.

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Charles G Durbin Jr MD and
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Pleuritic Chest Pain and Exertional Dyspnea in a Middle-Aged Smoker

Digpal Chauhan MD

A 53-year-old man with a 25-pack-year smoking history was admitted to the hospital with the chief complaint of right-side pleuritic chest pain associated with some exertional dyspnea. The patient denied cough, sputum production, hemoptysis, or arthralgias.

The patient's medical history was negative for sinopulmonary infections but positive for allergic rhinitis, and he had experienced bronchial asthma in the remote past. There was no history of extrapulmonary malignancy or lymphoma.

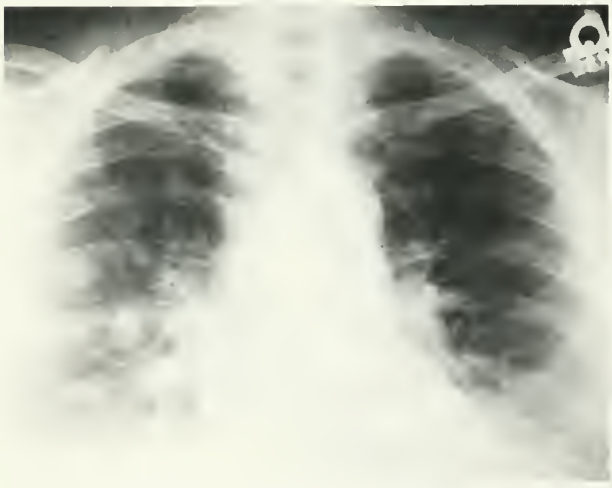

Fig. 1. Posteroanterior chest film of 53-year-old man with right-side pleuritic chest pain and exertional dyspnea.

Dr Chauhan is Chief of Pulmonary Medicine, Eisenhower VA Medical Center, Leavenworth, Kansas.

Examination revealed no adenopathy, elevated temperature, or clubbing. Liver span was normal. Chest percussion and auscultation revealed dullness

Fig. 2. Right-lateral decubitus view of patient in Fig. 1.

Questions

Radiographic Findings: How do you interpret the radiographs shown in Figures 1 and 2?
Further Tests: What further testing is indicated?
Differential Diagnosis: What should be considered in the differential diagnosis?
Diagnosis: What is the most probable diagnosis?
Therapy: What therapy is indicated?

with diminished breath sounds in the right base and scattered expiratory wheezes in both lung fields. Chest radiographs were taken (Figs. 1 & 2). Results of initial laboratory tests are shown in Table 1.

Table 1. Laboratory Tests in 53-Year-Old Man with Pleuritic Chest Pain and Exertional Dyspnea

Test	Normal Value	Patient Value
Leukocyte count (WBC)	2.5 × 10⁹/L	9.7 × 10⁹/L
Serum eosinophil count	< 3%	11%
Serum IgE	< 100 mg/dL	672 mg/dL
Serum precipitins for *Aspergillus fumigatus*		negative
Erythrocyte sedimentation rate (ESR)	0-20 mm/h	45 mm/h
Alkaline phosphatase	36-92 U/L	109 U/L
FEV_1	3.39 L	2.68 L
FVC	4.65 L	3.90 L
FEV_1/FVC	> 75%	68%

Answers and Discussion on Next Page

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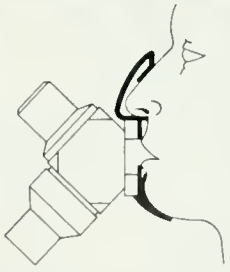

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Answers

Radiographic Findings: The posteroanterior chest film (Fig. 1) reveals multiple pulmonary nodules in both lungs, right pleural effusion, and bibasilar interstitial infiltrates. The right-lateral decubitus film (Fig. 2) shows free layering of pleural fluid.

Further Tests: Analysis of pleural fluid, open lung biopsy, serum titers, and examination and culturing of bronchial washings may be indicated. Radiographs of paranasal sinuses and abdomen, antibody titers, and tests for the presence of parasites may help establish the diagnosis.

Pleural fluid analysis revealed an exudate with 40% eosinophils (normal < 3%). Cultures and cytology were negative for cancer cells. Examination and culture of bronchial washings were negative for cancer cells, acid-fast bacillus, and fungi.

Differential Diagnosis: The differential diagnosis of a condition marked by the presence of multiple pulmonary nodules and pleural effusion includes metastatic disease, noninfectious granulomas (eg, rheumatoid necrobiotic nodules and lymphomatoid granulomatosis), infectious granulomas (particularly fungal disease like histoplasmosis and coccidiomycosis), and pulmonary vasculitides (particularly Churg-Strauss syndrome, or CSS; Wegner's; and necrotizing sarcoid granulomatosis).[1] This patient's history of allergic rhinitis, the spirometry results indicating airflow obstruction, and the eosinophilic pleural effusion (40% eosinophils) narrows the differential diagnosis to allergic angiitis and granulomatosis (CSS), allergic bronchopulmonary aspergillosis, and eosinophilic lung disease due to drugs and parasites.[2]

Diagnosis: This patient had a classic presentation of CSS, with his history of allergic diathesis, bronchial asthma, and eosinophilia in sputum, peripheral blood, and pleural fluid. Transbronchial biopsy was nondiagnostic, but open-lung biopsy revealed pulmonary vasculitis compatible with the diagnosis.

Possible Therapy: Steroids are the treatment of choice in CSS,[3] with the usual dose varying from 1-2 mg/kg/day depending on the severity of the disease. Disappearance of eosinophilia is an encouraging sign and suggests adequate therapy. Cases refractory to steroid therapy may require cytotoxic therapy like cyclophosphamide or azathioprine.[4]

Discussion

Churg-Strauss syndrome was first described in 1951 by the two pathologists for whom the condition is named.[5] In addition to the pulmonary involvement as manifested by this patient, CSS can include cardiac involvement with hypertension, pericarditis, and cardiac failure; cutaneous manifestations with purpura, nodules, and urticaria; mononeuritis multiplex; proteinuria; renal insufficiency; abdominal pain; and diarrhea. Steroid treatment often leads to remission of symptoms. Five-year survival in a series reported from Mayo Clinic was 62% with median survival of 9 years.[5,6]

Our patient responded to 60 mg of prednisone, which was gradually reduced according to clinical response. Dyspnea, pulmonary nodules, infiltrates, and pleural effusion resolved. He was followed for about 2 years and was then lost to follow-up.

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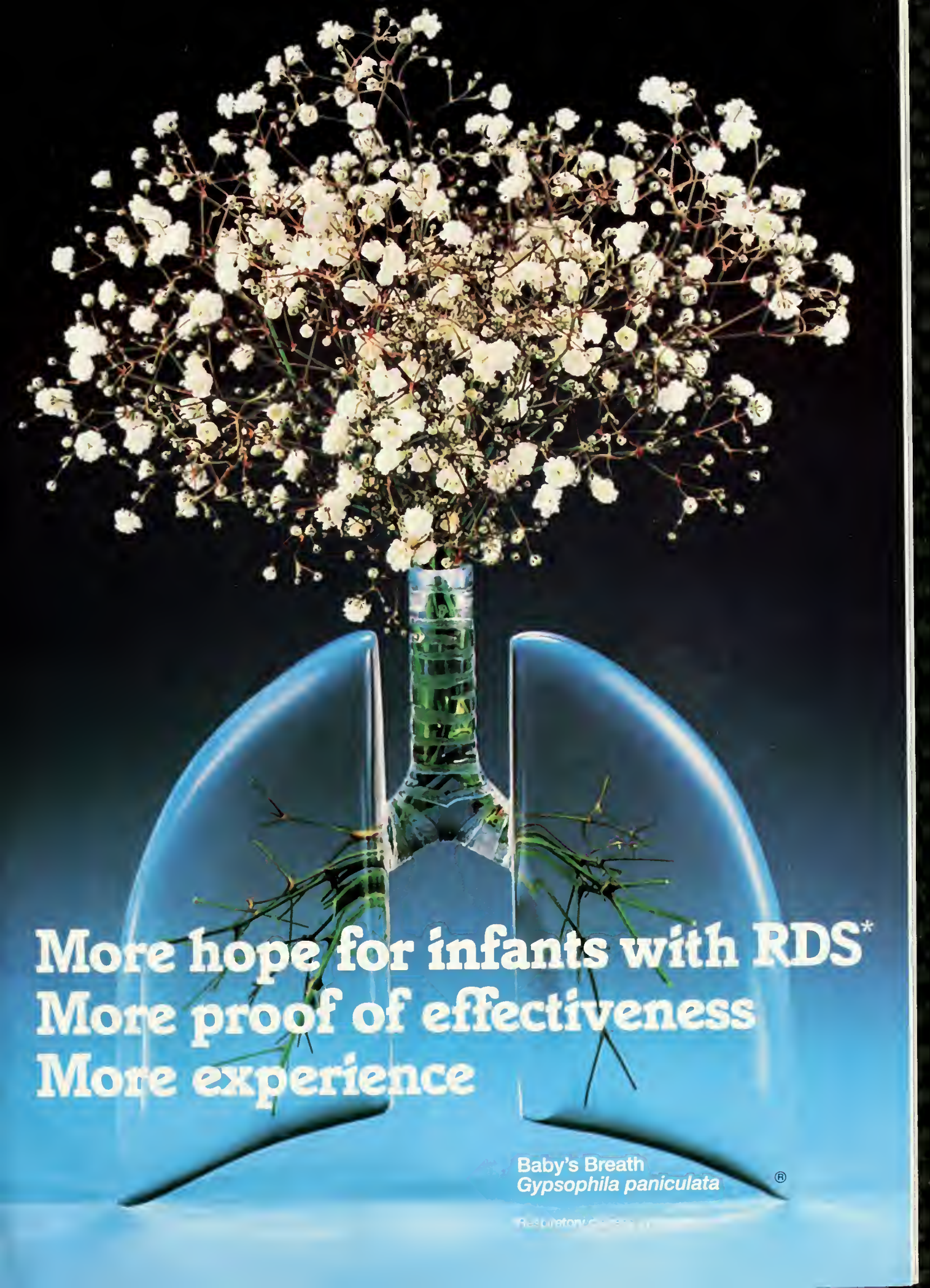
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1 **Prophylactic** treatment of infants with birth weights of less than 1350 grams who are at risk of developing ROS (see PRECAUTIONS),

2 **Prophylactic** treatment of infants with birth weights greater than 1350 grams who have evidence of pulmonary immaturity, and

3 **Rescue** treatment of infants who have developed ROS

CONTRAINDICATIONS: There are no known contraindications to treatment with Exosurf Neonatal

WARNINGS: **Intratracheal Administration Only**: Exosurf Neonatal should be administered only by instillation into the trachea. **General**: The use of Exosurf Neonatal requires expert clinical care by experienced neonatologists and other clinicians who are accomplished at neonatal intubation and ventilatory management. Adequate personnel, facilities, equipment and medications are required to optimize perinatal outcome in premature infants. Instillation of Exosurf Neonatal should be performed **only** by trained medical personnel experienced in airway and clinical management of unstable premature infants. Vigilant clinical attention should be given to all infants prior to, during, and after administration of Exosurf Neonatal. **Acute Effects**. Exosurf Neonatal can rapidly affect oxygenation and lung compliance. **Lung Compliance**: If chest expansion improves substantially after dosing, peak ventilator inspiratory pressures should be reduced immediately, without waiting for confirmation of respiratory improvement by blood gas assessment. Failure to reduce inspiratory ventilator pressures rapidly in such instances can result in lung overdistention and fatal pulmonary air leak. **Hyperoxia**: If the infant becomes pink and transcutaneous oxygen saturation is in excess of 95%, FiO_2 should be reduced in small but repeated steps (until saturation is 90 to 95%) without waiting for confirmation of elevated arterial pO_2 by blood gas assessment. Failure to reduce FiO_2 in such instances can result in hyperoxia. **Hypocarbia**: If arterial or transcutaneous CO_2 measurements are <30 torr, the ventilator rate should be reduced at once. Failure to reduce ventilator rates in such instances can result in marked hypocarbia, which is known to reduce brain blood flow. **Pulmonary Hemorrhage**: In the single study conducted in infants weighing <700 grams at birth, the incidence of pulmonary hemorrhage (10% vs 2% in the placebo group) was significantly increased in the Exosurf Neonatal group. None of the five studies involving infants with birth weights >700 grams showed a significant increase in pulmonary hemorrhage in the Exosurf Neonatal group. In a cross-study analysis of these five studies, pulmonary hemorrhage was reported for 1% (14/1420) of infants in the placebo group and 2% (27/1411) of infants in the Exosurf Neonatal group. Fatal pulmonary hemorrhage occurred in three infants, two in the Exosurf Neonatal group and one in the placebo group. Mortality from all causes among infants who developed pulmonary hemorrhage was 43% in the placebo group and 37% in the Exosurf Neonatal group. Pulmonary hemorrhage in both Exosurf Neonatal and placebo infants was more frequent in infants who were younger, smaller, male, or who had a patent ductus arteriosus. Pulmonary hemorrhage typically occurred in the first 2 days of life in both treatment groups. In more than 7700 infants in the open, uncontrolled study, pulmonary hemorrhage was reported in 4%, but fatal pulmonary hemorrhage was reported rarely (0.4%). In the controlled clinical studies, Exosurf Neonatal treated infants who received steroids more than 24 hours prior to delivery or indomethacin postnatally had a lower rate of pulmonary hemorrhage than other Exosurf Neonatal treated infants. Attention should be paid to early and aggressive diagnosis and treatment (unless contraindicated) of patent ductus arteriosus during the first 2 days of life (while the ductus arteriosus is often clinically silent). Other potentially protective measures include attempting to decrease FiO_2 preferentially over ventilator pressures during the first 24 to 48 hours after dosing, and attempting to decrease PEEP minimally for at least 48 hours after dosing. **Mucous Plugs**: Infants whose ventilation becomes markedly impaired during or shortly after dosing may have mucous plugging of the endotracheal tube, particularly if pulmonary secretions were prominent prior to drug administration. Suctioning of all infants prior to dosing may lessen the chance of mucous plugs obstructing the endotracheal tube. If endotracheal tube obstruction from such plugs is suspected, and suctioning is unsuccessful in removing the obstruction, the blocked endotracheal tube should be replaced immediately.

PRECAUTIONS.

General: In the controlled clinical studies, infants known prenatally or postnatally to have major congenital anomalies, or who were suspected of having congenital infection, were excluded from entry. However, these disorders cannot be recognized early in life in all cases, and a few infants with these conditions were entered. The benefits of Exosurf Neonatal in the affected infants who received drug appeared to be similar to the benefits observed in infants without anomalies or occult infection. **Prophylactic Treatment–Infants <700 Grams**: In infants weighing 500 to 700 grams, a single prophylactic dose of Exosurf Neonatal significantly improved FiO_2 and ventilator settings, reduced pneumothorax and reduced death from ROS, but increased pulmonary hemorrhage (see WARNINGS). Overall mortality did not differ significantly between the placebo and Exosurf Neonatal groups (see Table 1 in full product information). Data on multiple doses in infants in this weight class are not yet available. Accordingly, clinicians should carefully evaluate the potential risks and benefits of Exosurf Neonatal administration in these infants. **Rescue Treatment–Number of Doses**: A small number of infants with ROS have received more than two doses of Exosurf Neonatal as rescue treatment. Definitive data on the safety and efficacy of these additional doses are not available. **Carcinogenesis, Mutagenesis, Impairment of Fertility**: Exosurf Neonatal at concentrations up to 10,000 µg/plate was not mutagenic in the Ames Salmonella assay. Long-term studies have not been performed in animals to evaluate the carcinogenic potential of Exosurf Neonatal. The effects of Exosurf Neonatal on fertility have not been studied.

ADVERSE REACTIONS

General: Premature birth is associated with a high incidence of morbidity and mortality. Despite significant reductions in overall mortality associated with Exosurf Neonatal, some infants who received Exosurf Neonatal developed severe complications and either survived with permanent handicaps or died.

In controlled clinical studies evaluating the safety and efficacy of Exosurf Neonatal, numerous safety assessments were made. In infants receiving Exosurf Neonatal, pulmonary hemorrhage, apnea and use of methylxanthines were increased. A number of other adverse events were significantly reduced in the Exosurf Neonatal group, particularly various forms of pulmonary air leak and use of pancuronium. Tables 3 and 4 summarize the results of the major safety evaluations from the controlled clinical studies.

Table 3 Safety Assessments[a]—Prophylactic Treatment

Number of Doses / Birth Weight Range	Single Dose 500 to 700 grams		Single Dose 700 to 1350 grams		Single Dose 700 to 1100 grams		1 vs 3 Doses 700 to 1100 grams	
Treatment Group / Number of Infants	Placebo (Air) N=108	EXOSURF N=107	Placebo (Air) N=193	EXOSURF N=192	Placebo (Air) N=222	EXOSURF N=224	EXOSURF 1 Dose N=356	EXOSURF 3 Doses N=360
	% of Infants		% of Infants		% of Infants		% of Infants	
Intraventricular Hemorrhage (IVH)								
Overall	51	57	31	27	36	36	38	35
Severe IVH	26	25	10	8	13	14	9	9
Pulmonary Air Leak (PAL)								
Overall	52	48	16	11	32	25	29	27
Pneumothorax	23	10*	5	6	19	11*	14	12
Pneumopericardium	1	4	2	0	<1	1	1	1
Pneumomediastinum	2	1	2	3	7	1**	3	2
Pulmonary Interstitial Emphysema	43	44	13	7*	26	20	23	22
Death from PAL	4	6	<1	<1	2	1	2	1
Patent Ductus Arteriosus	49	53	66	70	50	55	59	57
Necrotizing Enterocolitis	2	4	11	13	3	4	6	2*
Pulmonary Hemorrhage	2	10**	2	4	1	4	4	6
Congenital Pneumonia	4	4	2	4	2	2	1	1
Nosocomial Pneumonia	10	10	2	4	4	7	14	15
Non-Pulmonary Infections	33	35	34	39	28	29	35	34
Sepsis	30	34	30	34	23	24	30	27
Death From Sepsis	4	4	3	3	1	2	3	2
Meningitis	4	6	3	1	2	3	1	2
Other Infections	7	4	5	3	6	10	10	11
Major Anomalies	3	1	2	4	7	4	4	4

Table 3 Safety Assessments[a]—Prophylactic Treatment (Cont.)

Number of Doses / Birth Weight Range	Single Dose 500 to 700 grams		Single Dose 700 to 1350 grams		Single Dose 700 to 1100 grams		1 vs 3 Doses 700 to 1100 grams	
Treatment Group / Number of Infants	Placebo (Air) N=108	EXOSURF N=107	Placebo (Air) N=193	EXOSURF N=192	Placebo (Air) N=222	EXOSURF N=224	EXOSURF 1 Dose N=356	EXOSURF 3 Doses N=360
	% of Infants		% of Infants		% of Infants		% of Infants	
Hypotension	70	77	52	47	59	62	54	50
Hyperbilirubinemia	22	21	63	61	27	31	20	21
Exchange Transfusion	4	3	1	2	2	2	3	1
Thrombocytopenia[b]	21	25	not available		9	8	12	10
Persistent Fetal Circulation	0	1	1	1	0	2*	1	<1
Seizures	11	8	2	2	11	9	6	5
Apnea	34	33	76	73	55	65*	62	68
Drug Therapy								
Antibiotics	96	99	98	96	98	99	>99	99
Diuretics	55	60	39	37	59	63	64	65
Anticonvulsants	14	18	23	24	20	16	9	8
Inotropes	46	40	20	20	26	20	28	27
Sedatives	62	71	65	64	63	57	52	52
Pancuronium	19	11	22	14*	19	13*	15	11
Methylxanthines	38	43	77	77	61	72*	75	82*

[a] All parameters were examined with "as-treated" analyses. * $p<0.05$ ** $p<0.01$
[b] Thrombocytopenia requiring platelet transfusion

Table 4 Safety Assessments[a]—Rescue Treatment

Number of Doses / Birth Weight Range	Two Doses 700 to 1350 grams		Two Doses 1250 grams and above	
Treatment Group / Number of Infants	Placebo (Air) N=213	EXOSURF N=206	Placebo (Air) N=622	EXOSURF N=615
	% of Infants		% of Infants	
Intraventricular Hemorrhage (IVH)				
Overall	48	52	23	18*
Severe IVH	13	9	5	4
Pulmonary Air Leak (PAL)				
Overall	54	34***	30	18***
Pneumothorax	29	20*	20	10***
Pneumopericardium	4	1	1	2
Pneumomediastinum	8	4	5	2**
Pulmonary Interstitial Emphysema	48	25***	24	13***
Death from PAL	7	3	<1	1
Patent Ductus Arteriosus	66	57	54	45*
Necrotizing Enterocolitis	3	3	1	2
Pulmonary Hemorrhage	3	1	<1	1
Congenital Pneumonia	2	3	2	2
Nosocomial Pneumonia	5	7	2	2
Non-Pulmonary Infections	19	22	13	13
Sepsis	15	17	8	8
Death From Sepsis	<1	<1	1	<1
Meningitis	1	<1	1	<1*
Other Infections	5	8	5	6
Major Anomalies	3	3	4	4
Hypotension	62	57	50	39**
Hyperbilirubinemia	17	19	12	10
Exchange Transfusion	3	4	1	2
Thrombocytopenia[b]	10	11	4	<1**
Persistent Fetal Circulation	1	1	6	2**
Seizures	10	10	6	3*
Apnea	48	65**	37	44*
Drug Therapy				
Antibiotics	100	99	98	98
Diuretics	60	65	45	34***
Anticonvulsants	17	17	10	5**
Inotropes	36	31	27	16***
Sedatives	72	68	76	64***
Pancuronium	34	17**	33	19***
Methylxanthines	62	74**	49	53

[a] All parameters were examined with "as-treated" analyses. * $p<0.05$ ** $p<0.01$ *** $p<0.001$
[b] Thrombocytopenia requiring platelet transfusion. See WARNINGS. **Abnormal Laboratory Values**: Abnormal laboratory values are common in critically ill, mechanically ventilated, premature infants. A higher incidence of abnormal laboratory values in the Exosurf Neonatal group was not reported. **Events During Dosing**: Data on events during dosing are available from more than 8800 infants in the open, uncontrolled clinical study (Table 5).

Pulmonary Hemorrhage

Table 5 Events During Dosing in the Open, Uncontrolled Study[a]

Treatment Type / Number of Infants	Prophylactic Treatment N=1127	Rescue Treatment N=7711
	% of Infants	% of Infants
Reflux of Exosurf	20	31
Drop in O_2 saturation (≥20%)	6	22
Rise in O_2 saturation (≥10%)	5	6
Drop in transcutaneous pO_2 (≥20 mm Hg)	1	8
Rise in transcutaneous pO_2 (≥20 mm Hg)	2	5
Drop in transcutaneous pCO_2 (≥20 mm Hg)	<1	1
Rise in transcutaneous pCO_2 (≥20 mm Hg)	1	3
Bradycardia (<60 beats/min)	1	3
Tachycardia (>200 beats/min)	<1	<1
Gagging	1	5
Mucous Plugs	<1	<1

[a] Infants may have experienced more than one event. Investigators were prohibited from adjusting FiO_2 and/or ventilator settings during dosing unless significant clinical deterioration occurred.

Reflux: Reflux of Exosurf Neonatal into the endotracheal tube during dosing has been observed and may be associated with rapid drug administration. If reflux occurs, drug administration should be halted and, if necessary, peak inspiratory pressure on the ventilator should be increased by 4 to 5 cm H_2O until the endotracheal tube clears. ***>20% Drop in Transcutaneous Oxygen Saturation***: If transcutaneous oxygen saturation declines during dosing, drug administration should be halted and, if necessary, peak inspiratory pressure on the ventilator should be increased by 4 to 5 cm H_2O for 1 to 2 minutes. In addition, increases of FiO_2 may be required for 1 to 2 minutes. ***Mucous Plugs***: See WARNINGS.

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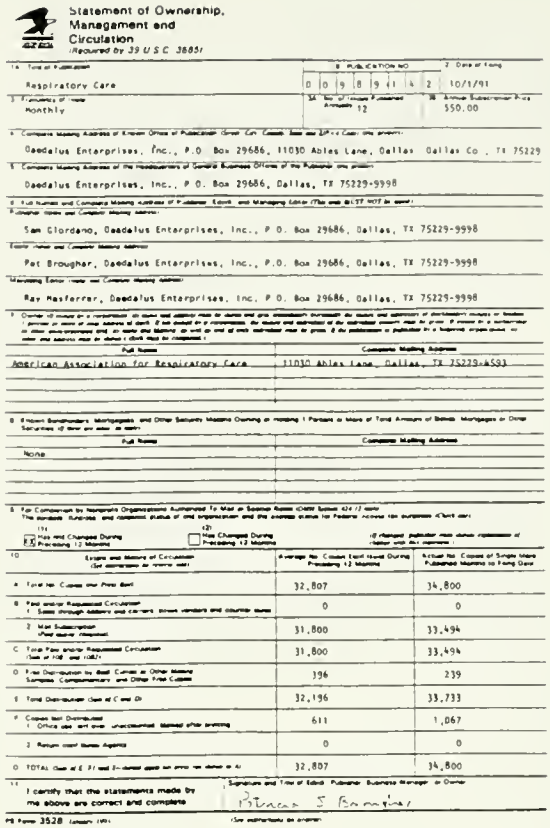

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Respiratory Care Certification Guide, by James R Sills MEd CPFT RRT. Soft-cover, illustrated, 412 pages. St Louis: Mosby Year Book Inc, 1991. $27.95.

How nice to review a really useful book! **Respiratory Care Certification Guide** is a must in the armamentarium of anyone preparing for the National Board for Respiratory Care (NBRC) Entry-Level Certification (CRTT) exam.

It is clear from the onset that the author, who is Director of Respiratory Care Programs at Rock Valley College (Rockford IL), is concerned about adequately preparing his students for working as respiratory care technicians and for passing the entry-level exam.

Respiratory Care Certification Guide "is designed to cover in detail all of the areas of knowledge, skills, and professional attitudes required of technicians by the NBRC." The text has been synthesized around the NBRC's June 1987 Detailed Content Outline, and progresses logically from patient assessment (which the author calls "the cornerstone of appropriate care") to pulmonary rehabilitation and home care.

Headings throughout the text are followed by two alphanumeric codes; the first (in parentheses) is the NBRC code for the subject found in the NBRC's Detailed Content Outline, and the second (in brackets) is the NBRC's code for difficulty level (Recall, Application, and Analysis).

I find the "Introduction for Examinees" to be clear and to the point. Especially helpful is the author's "Relative Weights of the Various Tested Areas on the Entry Level Exam," in which he has analyzed the content of each of the 140 questions on Versions II, III, and IV of the NBRC's Self-Assessment Entry-Level Exams (SAEs). Sills reflects clearly his view that Sections 1, 2, and 3 (Patient Assessment, Blood Gases, and Pulmonary Function Testing) in particular must be thoroughly understood. I found it interesting that he placed PFTs above such indispensable content areas as Aerosol Therapy (Unit 6) and Mechanical Ventilation (Unit 13, a subject from which questions come most frequently), until I recalled he is a CPFT as well as an RRT!

It is important to understand that **Respiratory Care Certification Guide** is a synopsis of entry-level content—not a textbook of background information. Therefore, the **Guide**'s probably most useful as a supplemental resource to be introduced toward the end of an entry-level curriculum or as a review source for the entry-level graduate shortly before attempting the NBRC's CRTT exam.

The illustrations (used freely throughout the text) are of real value to the reader, as are the self-study, multiple-choice questions (keyed) at the end of each section. I also find the Index to be thorough.

In summary, I highly recommend that entry-level respiratory care students and/or faculty preparing students for the NBRC's Certification (CRTT) exam add a copy of **Respiratory Care Certification Guide** to their library, along with other similar soft-cover review texts that have been reviewed in this journal: **Master Guide For Passing The Respiratory Care Credentialing Exams**, 2nd ed, by TM Krider, R Meyer, and W Syvertsen (Respir Care 1990;35:435); **Respiratory Care: National Board Review**, by CA Brainard (Respir Care 1985;30:134); and **Comprehensive Review in Respiratory Care**, 2nd ed, by WV Wojciechowski and E Neff (Respir Care 1989;34:42).

It may be that the best proof is 'in the pudding.' I asked four full-time instructors in our entry-level Respiratory Care Technician Certification Program what they think of **Respiratory Care Certification Guide**. They all consider it to be the most up-to-date, comprehensive review text for the NBRC entry-level content in existence, and use it for their students. The pudding, they say, tastes pretty good.

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Emergency Airway Management, Michael S Gorback MD. Soft-cover, illustrated, 183 pages. St Louis: Mosby Year Book Inc, 1990. $32.95.

Emergency Airway Management is an informative handbook that addresses the problems of managing the airway in emergency situations. The chapters evolve in a very logical sequence that begins with basic anatomy, proceeds through equipment and assessment, addresses basic and advanced airway management techniques, and concludes with adjunctive techniques (with emphasis on important pharmacologic agents).

The book is written in an outline format, which has several advantages: (1) the organization of ideas is very clear, (2) key points can be readily found, and (3) reading can be done very rapidly. However, the style requires that the reader pay close attention and concentrate on every statement. Despite this style (which might be considered by some to be a shortcoming), I believe that the information is remarkably complete and that numerous clinical "pearls" are found. These range from the hemodynamic responses to intubation with valvular heart disease to practical discussions on nebulizing topical anesthetics. Clever phraseology used throughout the book makes its reading enjoyable, and numerous personal

experiences also help give the book a 'human' feel. One particularly insightful comment regarding airway management: "Always remember the first rule of wing walking—never let go of one thing until you have a firm grip on another."

Perhaps the greatest asset of this book is its photography, particularly the pictures of cadavers used to demonstrate a variety of airway management situations. I have used a number of slides made from these photographs to illustrate the important points of airway management in teaching. A short series of color photographs of laryngoscopic and bronchoscopic views of the airways (which are also included) are technically excellent; however, they don't appear to add a great deal to the book's message and, because they are color, unfortunately have probably driven the price up.

Overall, the information provided is well organized and complete. These features, coupled with the superb illustrations, make this an outstanding resource for all clinicians involved in managing airways in emergency conditions. (The dosing guidelines and practical tips are particularly useful.) Even those who deal only with basic airway care will find the illustrations fascinating and the book a useful reference.

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Respiratory Disease in the Immunocompromised Host, edited by James Shelhamer, Phillip Pizzo, Joseph E Parrillo, and Henry Masur. Hardcover, illustrated, 784 pages. Philadelphia: JB Lippincott Co, 1990. $100.00.

As the spectrum of immunocompromising disease grows, so too does the challenge of mastering the care of these patients—the goals of which are "the identification of a specific process with a defined therapy and prognosis." For a rapidly growing and evolving field, the traditional source of information has been the primary medical literature. **Respiratory Disease in the Immunocompromised Host** contributes immensely by presenting an exhaustive series of state-of-the-art reviews of both infectious and noninfectious respiratory illness that may affect patients broadly considered to be immunocompromised.

The 47 chapters in this text (organized into 4 major sections) are written by 72 contributors, many of whom are widely recognized authorities on their respective topics.

Section 1 (Predisposition to Disease) contains 3 chapters that review the physiology of normal pulmonary host offense and the impact of impairing insults (eg, cytotoxic drug effects).

Section 2 (Diagnostic Approaches) is made up of 12 chapters that examine the complete spectrum of imaging, physiologic testing, biopsy, and histologic-cytologic assessment of diagnostic specimens.

Section 3 (Specific Causes of Respiratory Dysfunction) has 21 chapters that review specific individual infections (15 chapters) and noninfectious causes of respiratory compromise in immunocompromised patients (6 chapters).

Section 4 (Diagnostic and Therapeutic Problems in Specific Patient Populations) contains 10 chapters that consider specific clinical settings (eg, HIV hosts and glucocorticoid recipients) and review the appropriate diagnostic, therapeutic, and preventive approaches.

Section 5 (Prevention of Respiratory Disease) reviews, in a single chapter, broadly applicable preventive strategies such as protective isolation, antimicrobial suppression, and device manipulation.

True to its goal of being a definitive textbook, individual chapters are comprehensive reviews that are exhaustively referenced and contain very citable tables and ample illustrations and photographs. Overall, controversies are identified and discussed with balanced and scholarly completeness. For example, the chapter entitled "Open Lung Biopsy" in Section 2 (Diagnostic Approaches) considers the seminal issues of "false-negative" and "false-positive" results in a way that reflects the authors' scholarly and practical clinical experience with this technique. This observation seems representative of the book.

The stated goal of the book is to be an up-to-date bible for diagnosing and treating immunocompromised patients. Its success in this regard suggests it should be in the personal libraries of those physicians who commonly treat such patients (ie, intensivists, pulmonologists, and infectious-disease specialists). Also, specific chapters on pulmonary function testing, on bronchoscopic techniques, and on diagnostic and therapeutic handling of specific populations (Section 4) should be of considerable value to ICU-based therapists caring for immunocompromised patients and to those respiratory care practitioners and investigators seeking complete treatment of the subject as of late 1990.

By selecting the rapidly evolving subject of respiratory disease in immunocompromised hosts, the editors take on the challenge of summarizing comprehensively a subject that is likely to change within several years of the book's availability. Interested clinicians and respiratory care practitioners can expect that subsequent editions of this book will provide a maturing classic in the field.

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The Cleveland Clinic Foundation
Cleveland, Ohio

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HFOV—Recent Developments

We read with interest the recent article "Neonatal and Pediatric High-Frequency Ventilation: Principles and Practice."[1] Dr Coghill and his associates have provided a most interesting and informative survey of the subject, providing a balanced view of the three types of devices currently available.

It is quite a challenge to pull together the necessary data related to a rapidly evolving technology like high-frequency ventilation. As indicated in the Journal, the article was based on a presentation made by Dr Carlo in December 1990. Since then the status of our high-frequency ventilator, the SensorMedics 3100 HFOV, has changed.

At the end of March 1991, the 3100 HFOV was approved by the Food and Drug Administration for ventilatory support and treatment of neonates with respiratory failure and barotrauma—a much broader approval than that received by the other two high-frequency ventilators, which are specified only for application to infants with air leaks for whom conventional ventilation is judged to be failing. Although out-of-label use with its associated risk is a decision that each clinician and institution must address individually, it is legally required of the manufacturer to clearly promote use only for approved indications.

The authors[1] note that "no data exist to indicate that HFV can prevent the development of air leaks." However, Clark et al[2] in an abstract presented at the 1990 ATS meeting and in a paper now in press[3] presented evidence to support that the number of infants mechanically ventilated more than 30 days and the incidence of chronic lung disease were significantly less in infants supported by HFOV vs conventional ventilators. In addition, since the Coghill et al paper was written, the results of a multicenter randomized trial of the 3100 have been presented by the investigators in the HiFO Study Group at the Snowbird Conference on High Frequency Ventilation in April 1991 and at other meetings.

Finally, as noted in the Table of Comparisons in the article, Dr Cornish's results on 15 ECMO candidates indicated a reduced need for ECMO. As indicated in the discussion section of the Coghill et al article, this work was continued and published by the deLemos group.[4] Not mentioned was that these results on 46 neonates, although still not controlled, are certainly much more convincing than the 15-patient pilot study.

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The authors respond:

We have observed with interest the preliminary presentation of selected data from the multicenter HiFO study. We look forward to evaluating the completed paper after its publication. In our opinion, controlled studies of high-frequency ventilation in candidates for extracorporeal membrane oxygenation are necessary.

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Black Precipitate Found in Puritan-Bennett 7200 Ventilator Cascade

Humidity systems in most mechanical ventilators are designed for use with water only. We report on a black precipitate found in the Cascade of a Puritan-Bennett (PB) 7200 ventilator attached to a lung-transplant patient.

During the first 11-7 shift check of a ventilator being used to support a lung-transplant patient, the therapist noted that the reservoir of the Cascade humidifier was filled with a dark precipitate. The Cascade was immediately removed and the patient lavaged with saline and suctioned. No dark particles were suctioned from the endotracheal tube. The ventilator tubing was then changed and examined for any visible deposits of the dark particulate matter, but none were found. After the liquid had been emptied from the Cascade, a dark thin coating and some clumps resembling graphite were seen on the tower housing and the sides of the reservoir. One observer noted that the substance looked like toner from a copying machine. When quizzed, the therapists and nurses reported no unusual occurrences with the ventilator.

Three weeks later, at the first ventilator check on the 3-11 shift, the same kind of precipitate was found in the Cascade but in a larger quantity than in the previous incident. (This was the same ventilator and the same patient as in the first incident.) Another ventilator was provided for the patient. The inlet and outlet filters and the gas circuit through the PB 7200 were carefully examined by the equipment supervisor, but no precipitate could be found.

The fluid from the Cascade was sent to the Environmental Laboratory at the Southwestern Institute of Forensic Sciences in Dallas, Texas. After extensive testing by centrifugation, analysis using gas chromatography and mass spectrometry, energy dispersive x-ray, x-ray diffraction, microscopic examination, and specific color test, the material was found to be primarily nickel oxide (Ni_2O_3). X-ray diffraction indicated the presence of sodium chloride; no other organic or volatile compounds were found.

Sterile equipment and sterile water are routinely used with all lung-transplant patients. After the precipitate had been identified, we began to look for a substance containing nickel. Cascade heater housings are nickel-plated, and the addition of normal saline to a Cascade could cause nickel to be leached off the heater housing to form the black precipitate.

We duplicated the incident by setting up a heated Cascade filled with 0.9% (normal) saline. The heater was set on 9 (highest setting), and a continuous flow of 15 L/min was run through the Cascade. The exit temperature was maintained at 46-48°C. A black precipitate that appeared identical to the previous ones formed in the Cascade.

We determined that the Cascade had been filled with normal saline at the end of the shift. The nickel leached off, and the precipitate was then found. To prevent a recurrence, we have apprised all therapists who work in the intensive care units of the incidents, and have increased the availability of sterile water. No recurrences of the black precipitate have been observed.

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Using a/A to Determine F_{IO_2} Desired

I enjoyed Robert Chatburn's review of pediatric ventilator management,[1] but I believe that there may be an error in the legend of Figure 3. If the directions in the legend are followed, the F_{IO_2} needed for a P_{aO_2} of 80 will be about 0.63 and not 0.50.

I was alerted to this error because I calculated the F_{IO_2} needed using the following equation, which (like the nomogram in the article) is based on the assumed stable relationship of arterial and alveolar oxygen tensions over short periods of time. That is, unless something bad has happened:

$$\frac{P_{aO_2} \text{ at Time 1}}{P_{AO_2}} = \frac{P_{aO_2} \text{ at Time 2}}{P_{AO_2}}.$$

Therefore, algebraically:

$$F_{IO_2}' = \frac{[P_{aO_2}' + (1.2\ P_{aCO_2}')]}{a/A} \div P_B - 47.$$

where F_{IO_2}' = F_{IO_2} needed, P_{aO_2}' = P_{aO_2} desired, P_{aCO_2}' = P_{aCO_2} expected on the next ABG, a/A = present P_{aO_2}/P_{AO_2}, and P_B = barometric pressure.

Plugging in the numbers given in the article and assuming a barometric pressure of 760 yields an F_{IO_2}' of 0.63.

Of course, results obtained on real patients may vary from theory and it may be wise to err on the conservative side when choosing F_{IO_2}.

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Editor's Note: The figure and corrected legend are shown on Page 1248.

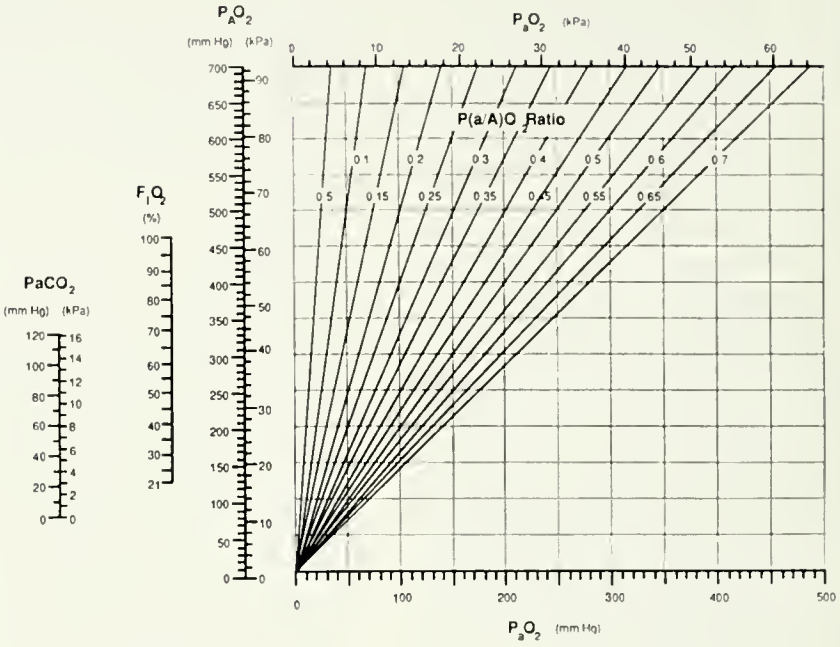

Fig. 3. Arterial-alveolar oxygen-tension-ratio (P_{aO_2}/P_{AO_2}) nomogram. If the old (ie, current) P_{aCO_2}, F_{IO_2}, and P_{aO_2} are known, the F_{IO_2} required for a desired P_{aO_2} can be estimated by assuming that P_{aO_2}/P_{AO_2} remains constant. A straight line connecting the old P_{aCO_2} and old F_{IO_2} will intersect the old P_{AO_2}. P_{aO_2}/P_{AO_2} is represented by the diagonal line connecting the origin of the graph ($P_{AO_2} = 0$, $P_{aO_2} = 0$) and the point representing the old P_{AO_2} and old P_{aO_2}. For example, a P_{aCO_2} of 40 torr [5.3 kPa] and an F_{IO_2} of 0.40 result in a P_{AO_2} of about 240 torr [31.9 kPa]. If the measured P_{aO_2} is 50 torr [6.7 kPa], P_{aO_2}/P_{AO_2} is about 0.2. If one moves along this diagonal line to a point above the desired P_{aO_2} (eg, 80 torr [10.6 kPa]), a horizontal line to the left of this point intersects the P_{AO_2} line at 400 torr [53.2 kPa]. A line connecting this number to an expected P_{aCO_2} of 40 torr indicates that an F_{IO_2} of about 0.63 will be required.

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Each year a highlight of the Annual Meeting of the American Association for Respiratory Care, the RESPIRATORY CARE OPEN FORUM, provides a platform for the reporting and discussion of some of the clinical studies, method and device evaluations, and case reports completed by members and friends during the previous year. During the 1991 OPEN FORUM in Atlanta, Georgia, December 7-10, more than 100 papers will be presented—clustered into 14 minisymposia. The abstracts of those papers are published here, sequenced as they will be presented. An index of the authors appears on Page 1326, with Presenters designated by boldface type.

Caregiver Education

College Admission Factors and Career Choices: A Survey of High School Seniors—Shelley C Mishoe MEd RRT, Kim L Valeri MS RRT, Medical College of Georgia; Laura H Beveridge MEd RRT, Augusta Health Alliance—*Augusta, Georgia.*

In an effort to improve our recruitment program, we conducted a research study to determine what factors influence high school seniors making decisions related to future careers and college education. **Materials & Methods**: We chose to survey an accessible sample of high school seniors from 3 schools in the public school system of Richmond County, Augusta GA. We distributed 505 surveys to senior students who were present on the days of data collection. Completion of the survey was voluntary. Each survey required about 10 min to complete 37 questions. Students were asked to indicate what career they intended to pursue, what people and factors influenced their choices, and their familiarity with and impressions of allied health professions. The final section asked students not interested in an allied health career to briefly state why. **Results**: 393 surveys were returned, 77.8% response rate; 53% of the respondents were White, 39% Black, 3% Hispanic, 2% Asian, and 3% other ethnic origins. 60% of the students indicated that they plan to attend college, 18% to attend vocational school, 10% to enter the military (data collected prior to Gulf War), 9% to work, and 3% no plans. 25% chose to pursue a health-related career, 25% undecided, 16% business, 15% engineering, 5% computer science, 5% education, 4% law, 4% science, and 1% religion. Only 44% approached their counselors for guidance; 72% chose the career for themselves, with parents and other relatives exhibiting the greatest influence. The majority indicated personal satisfaction, employment opportunities, and income as most important factors influencing their career choices; 76.5% had a favorable impression of allied health professions. Only 15% indicated they were very familiar with the allied health professions, 70% were vaguely familiar, and 15% knew nothing about allied health. Reasons for not selecting a health career included course requirements, difficulty of curricula, lack of awareness, dislike of sciences, and greater opportunities in non-health fields. Some feared being exposed to infectious diseases including TB, hepatitis, and AIDS. **Conclusions**: Our results and other studies point to lack of knowledge rather than lack of interest as the leading cause of low enrollment in allied health curricula. Recruitment efforts should focus on increasing awareness of opportunities in allied health; marketing the personal satisfaction, employment opportunities, and income potential of respiratory therapy to youth and their parents; dispelling myths about infectious diseases; and actively competing for students who view non-health careers as more desirable. (OF-91-002)

Cooperative Learning in an Associate Degree Respiratory Therapy Program—Cynthia Malinowski MA RRT, Loma Linda University, *Loma Linda, California.*

Teaching is accomplished predominately through lecturing in our program. We evaluated an instructional method that allows more active participation in the learning process and increased independence. **Method**: In Year 1, 13 students (control group) in a pulmonary anatomy and physiology class were taught 2 blocks of material by lecture only. The students were tested on

the two blocks of material with teacher-made multiple-choice exams, called Block 1 and Block 2 Exam, respectively. In Year 2, 13 students (experimental group) were taught the first block of material in the same manner as the control group, by lecture only, and then tested with the multiple-choice test used in Year 1. Block 1 Exam scores were compared between the control and experimental groups and no significant difference was seen in performance ($p > 0.05$). Experimental group then participated in a cooperative learning experience for Block 2. Students were assigned to groups and given material to teach to each other. Each student had a specific set of objectives to master and teach but could teach in whatever manner he deemed appropriate, including the use of audiovisuals. The same Block 2 Exam from the previous year was given to the experimental group. **Results**: The control group Block 1 Exam mean (SD) score was 81.6 (8.2) %, Block 2 82.2 (8.2) %. The mean difference between Blocks 1 and 2 was 1.5% and not significant ($p > 0.05$). Experimental group Block 1 Exam mean (SD) score was 77.2 (13.2) and Block 2 87.8 (12.2) %. The mean difference between Block 1 and Block 2 in the group with the cooperative learning was 10.6%. Improvement in performance was statistically significant (Population *t* test, $p < 0.05$). **Conclusion**: Use of the cooperative learning instructional method allowed more student control over the learning process and led to improved performance on teacher-made tests for adults in our respiratory therapy program. (OF-91-041)

Comparison of Effect of Learning Style Awareness on Test Performance of Students in a Nutrition Course—Charles Carroll EdD RRT. Daytona Beach Community College, *Daytona Beach Florida.*

A study was performed to compare the effect of learning-style awareness on test performance of students in a community college nutrition course. Because retention is a major problem for many students in community colleges, I sought to explore another potential tool that might enhance student success and retention. The null hypothesis was that there would be no significant difference between test scores when there was an awareness of learning style by the students and instructor and when there was no awareness. **Method:** The population for the study was two classes of students enrolled in a human nutrition class at Daytona Beach Community College. The freshman-level course has no prerequisites. One class served as the experimental group and the other class as the control group. As a regular part of the class, both groups were given lectures, participated in discussions, and had their performance evaluated with 10 identical unit tests. Six weeks into the course and following the administration of the first two tests, the experimental group was given a learning-style inventory. The results were shared with both the students and the instructor; they had known that a learning-style study was in progress but did not know the hypotheses being tested. No other effort to influence learning was made. A two-tailed *t* test was performed, with alpha at 0.05. **Results:** There were 32 degrees of freedom with a critical t of 2.042. The calculated t was 3.50; therefore, the null hypothesis was rejected, indicating that the experimental group (in which there was a learning-style awareness by the students and instructor) earned significantly higher test scores than the control group. **Conclusions:** The results of this study have important implications for all students and educators—showing that instructor and student awareness of learning styles can improve student's test performance. I believe that learning-style assessment and awareness should become a routine part of the education process. (OF-91-060)

Assessment of the Effectiveness of Replacing a Live-Animal Physiology Laboratory on Cardiac Output with Videodisc Instruction—John Phelps PhD, Jon Nilsestuen PhD RRT, Sunni Hosemann RN. SAHS University of Texas Health Science Center at Houston, *Houston, Texas.*

The purpose of this study was to investigate the instructional effectiveness of an interactive video program (IVP) on cardiac output compared to an instructional sequence that included a lecture and live-animal laboratory and taught the same content. The main hypothesis was that learning performance as measured by scores on a written posttest would be significantly higher for subjects who had completed an IVP on "Cardiac Output" than for those who had completed a similar instructional sequence consisting of a lecture and a live-animal laboratory. **Methods:** The content for a previously produced IVP on cardiac output was used in the development of a lecture and a live-animal (canine) laboratory. After completing a pretest, 54 volunteer undergraduate nursing and respiratory therapy students were randomly assigned to either the live-animal instructional sequence or the IVP. After each instructional treatment, each subject completed a posttest and an attitude assessment. **Analysis:** The pretest/posttest data were analyzed with an analysis of covariance procedure, using the pretest scores as the covariate. **Findings:** The research hypothesis was supported ($F = 5.31$, $p = 0.025$). Posttest scores of subjects completing the IVP treatment were significantly higher than those of subjects completing the live-animal laboratory sequence. Analysis of various attributes of the subjects did not reveal any interactions between them and the main treatment effect. Analysis of the post-treatment attitude assessment data revealed that subjects differed in their responses to questions involving "learning on my own" and "learning using computers." In both cases the IVP group responded with significantly greater frequency in the "Strongly Agree" and "Agree" categories. Finally, the time needed to complete each instructional treatment was very different for each group. The live-animal laboratory group required 5 hours to complete the instructional sequence; the IVP group required 1 hour. **Conclusions:** (1) Students learning cognitive concepts related to cardiac output via interactive video can do so at significantly higher levels of achievement than those learning the same content through a lecture and live-animal laboratory sequence, and in 1/5 the time; and (2) students are likely to have more favorable attitudes toward learning by themselves rather than in a group, and toward learning aided by computer. (OF-91-099)

Notetaking and Reviewing Study Notes: Effects on Learning Achievement with Interactive Videodisc (IVD) Instruction—Arthur Jones MA RRT, University of Texas Health Science Center, *Houston, Texas.*

Background: Study results have shown that IVD is an effective and efficient substitute for conventional instruction. Notetaking and review have been studied in context of conventional instruction but not for IVD. I sought to determine effects on learning time and achievement from an IVD lesson about cardiac output attributable to notetaking and reviewing: 2 formats of notes (1) learner's own notes and (2) matrix notes (a tabular organization of key concepts of lesson content provided to student that may be preferable for IVD lesson review because of its non-linear organization). **Methods & Materials:** Study used pretest, posttest, multiple-group experimental design with independent variables of notetaking and note reviewing. Dependent variables were learning achievement and time for lesson completion. 42 undergraduates from RT, nursing, and perfusion technology were randomized to 4 study conditions. 6 hypotheses were tested using ANCOVA, Tukey's HSD, and ANOVA. **Results:**

	Group 1* n = 9	Group 2 n = 11	Group 3 n = 11	Group 4 n = 11
Adjusted posttest mean (raw)	37.08	33.34	37.89	34.89
Mean time (hours)	1.698	1.396	1.565	1.887

*Group 1 = no notetaking or review; Group 2 = review of own notes; Group 3 = review of matrix notes; Group 4 = notetaking, review of own and matrix notes.

ANCOVA on posttest means, by group, with pretest means as covariate: $F = 1.454$, $p = 0.243$.

ANOVA on mean times, comparing Groups 1 & 3 with 2 & 4 combined: $F = 0.010$, $p = 0.921$.

Conclusions: Data suggest that notetaking does not increase the time required to complete an IVD lesson. Further, neither notetaking nor note reviewing appear to increase learning achievement from the medium. (OF-91-130)

The Use of Preadmission Criteria To Predict Academic Success in a Respiratory Care Curriculum—Timothy B Op't Holt EdD RRT, Crystal L Dunlevy EdD RRT. The Ohio State University, *Columbus, Ohio.*

Numerous studies have attempted to use various objective and subjective criteria to determine either the success of applicants to enter professional programs or their likelihood of successfully completing them. The intent of utilizing such screening procedures is to attempt to assure that valuable and scarce resources are not squandered on the academically or socially underprepared student, especially if others are waiting for admission. The literature indicates that the pre-professional grade point average (PPGPA) and the science-math GPA (SMGPA) have the highest predictive validity. Interview scores seem to correlate only with clinical abilities, allowing evaluation of personal characteristics and an assessment of the applicant's knowledge of the field. We proposed to determine the predictive validity of the preadmission criteria we currently use to admit students into the professional phase of our baccalaureate respiratory therapy program (the second 2 years). 79 students who were admitted into the professional program from 1982 through 1988 were the subjects. Independent variables included the year admitted into the program, age at time of admission, sex, science-math GPA (based upon a consistent list of courses), PPGPA, number of points scored on an interview, and the total number of points (based upon weighted GPAs and interview scores). Dependent variable was exit GPA. Regressions were performed between the independent variables and the dependent variable to determine the predictive validity of each independent variable. Linear regression revealed that 67% of the variation in exit GPA could be explained by all the variables together. However, several individual correlations were almost as predictive of the exit GPA: r^2 for SMGPA = 52%, for CUMGPA = 57%, and for weighted GPA points (GPAPTS = SMGPA score x 30 + PPGPA score × 15), $r^2 = 60\%$. We concluded that GPAs and the weighted GPA score correlate well with academic success, while there is no correlation between interview scores and exit GPA (r^2 = 0.02%) in our baccalaureate respiratory care curriculum. Further investigation into the need for a formal, scored interview process is warranted. (OF-91-163)

Critical Care Techniques and Equipment

The Flow-By Option on the Puritan-Bennett 7200a Ventilator Does Not Increase Auto-PEEP in the SIMV Mode—William Clark RRT, Daniel J Reily BS RRT, Lynda Gradwell MS RRT, John Sestito RRT. Hospital of the University of Pennsylvania, *Philadelphia, Pennsylvania.*

The 7200a ventilator has an option known as flow-by (FB). This allows a clinician-selected level of continuous flow from 5 to 20 L/min in the SIMV and CPAP modes. The addition of continuous flow may add resistance to exhalation, thereby increasing auto-PEEP (AP). This study was done to determine the effect of continuous flow on a pre-established level of AP. After a Total Extended Self-Test, the 7200a was attached to a Bio-Tek Instruments VT-1 Ventilator Tester. Compliance of 0.02 cm H_2O/L and resistance of 5.0 L · s · cm H_2O^{-1} were set on the VT-1. A screw clamp was applied to a 6.0-mm endotracheal tube (ETT) creating AP as in a previously evaluated AP model (Respir Care 1986;31:1075-1079). Pressure was monitored at both the proximal and distal ends of the ETT with calibrated Sorenson pressure transducers. We measured AP with a Model 78560A Hewlett-Packard strip-chart recorder. No humidifier was used. The ventilator was set for a square waveform in the SIMV mode. Initial V_T was set ($V_{T\,set}$) at 0.590 L. Delivered V_T ($V_{T\,del}$) was observed to be 0.560 L

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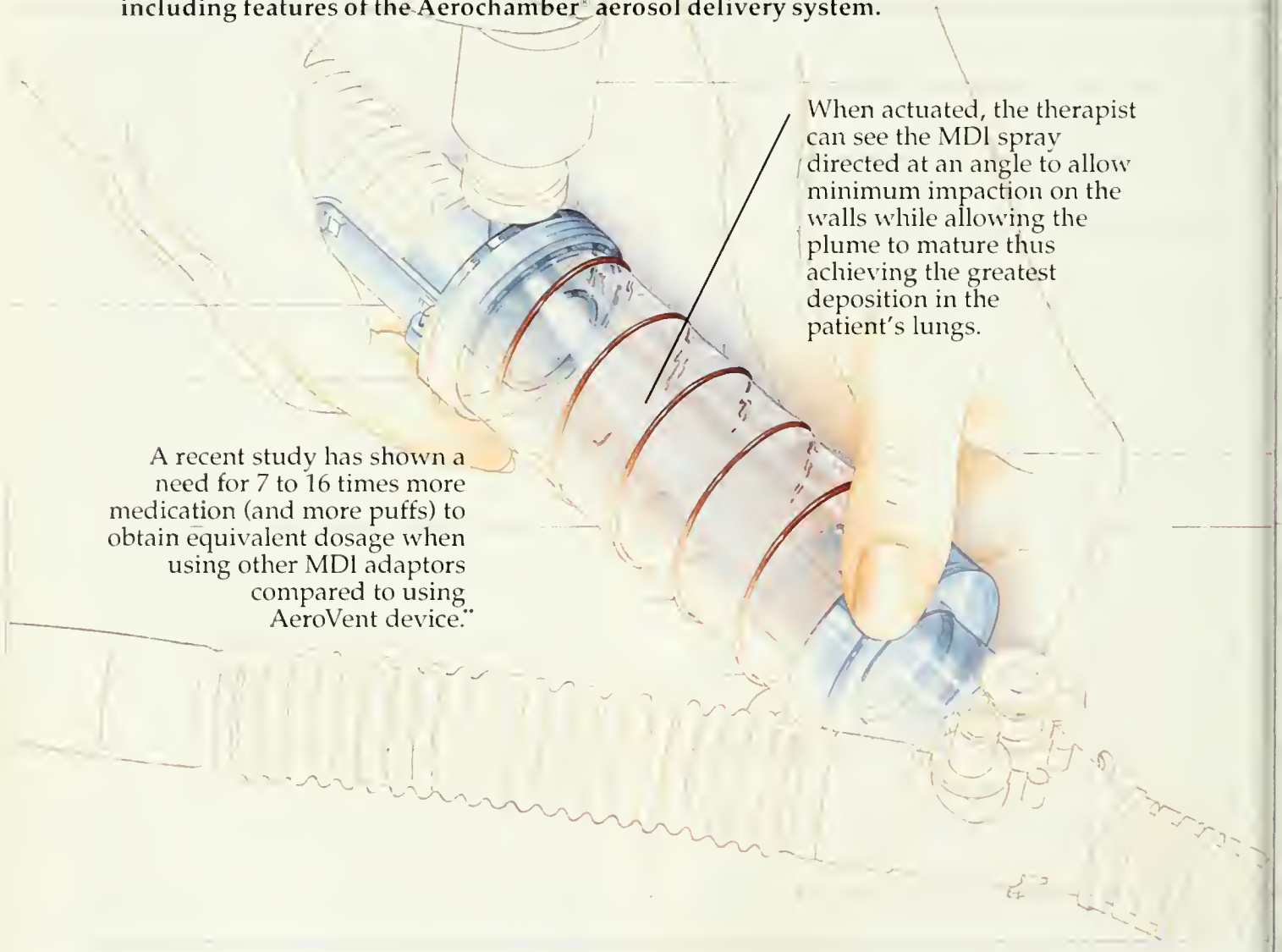

When actuated, the therapist can see the MDI spray directed at an angle to allow minimum impaction on the walls while allowing the plume to mature thus achieving the greatest deposition in the patient's lungs.

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** Metered Dose Inhaler Actuator-Adapters A Comparison of Particle Size and Drug Delivery Through an Endotracheal Tube - Richard P. Larson, RRT et all - Resp. Care. Nov '89 Vol 34 No 11

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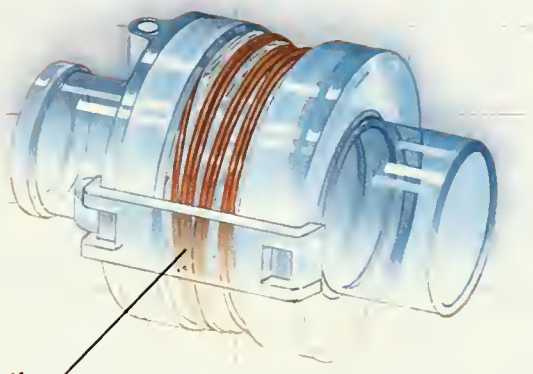

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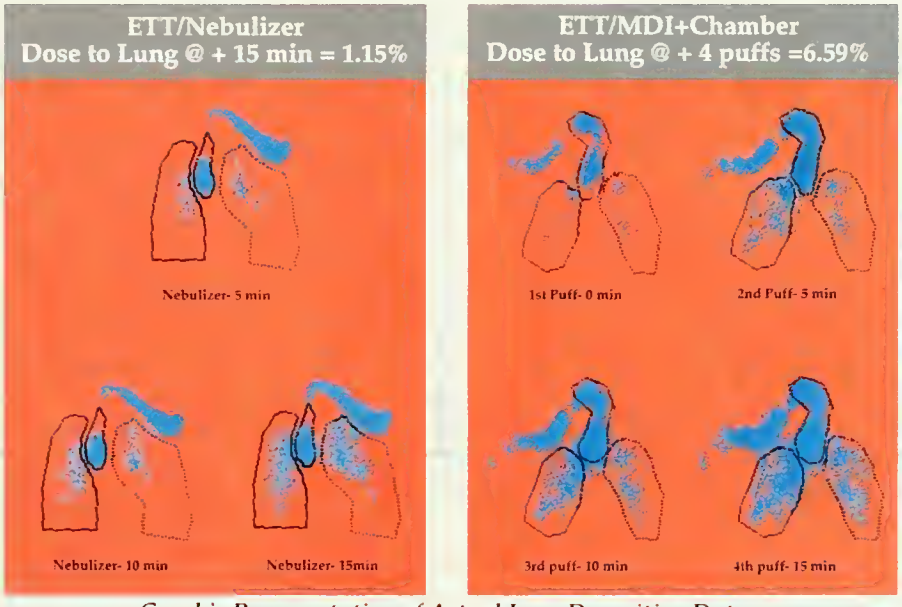

Graphic Representation of Actual Lung Deposition Data.

• Fuller HD, Dolovich MB, Posmituck G, Wong Pack W. and Newhouse MT Pressurized Aerosol versus Jet Aerosol Delivery to Mechanically Ventilated Patients Comparison of dose to the lungs. Am Rev Respir Dis, 141.440-444

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prior to adding FB. Subsequent V_T settings were altered to maintain $V_{T\text{-del}}$ at 0.560 L (±0.01 L). f was set at 25/min, and peak flow was kept constant at 25 L/min. Flow sensitivity was kept constant at 2 L/min. AP was then measured with base flow at 0, 5, 10, 15, and 20 L/min. 5 trials were done for each base flow for a total of 25 trials.

$V_{T\text{-set}}$ (L)	$V_{T\text{-del}}$ (L)	Base Flow (L/min)	Auto-PEEP (cm H_2O)
0.590	0.560	0	4.0
0.620	0.560	5	4.0
0.580	0.550	10	4.0
0.580	0.560	15	4.0
0.610	0.560	20	4.0

AP remained constant at +4.0 cm H_2O pressure for all 25 trials. The results indicate that FB on the 7200a ventilator does not increase AP in our test model. (OF-91-057)

Rapid Analysis of Exhaled CO_2 To Assess Endotracheal Tube Placement—Sharon Day RRT, Neil R MacIntyre MD, Larry Wooton RRT. Duke University Medical Center, *Durham, North Carolina.*

Introduction: Assessing proper placement of an endotracheal tube can be difficult. Standard techniques include visualization of tube in larynx, auscultation of chest and abdomen, assessment of compliance using the resuscitation bag, tube humidification, patient phonation, gastric contents in the tube, and radiologic assessment. Despite these techniques, intubations can be misplaced. We reasoned that the presence or absence of CO_2 may be a more rapid and specific assessment of tube placement. **Methods & Materials**: All endotracheal intubation attempts by Respiratory Care Services at Duke University Medical Center from July 1989 to October 1990 were studied. A Biochem 515 portable CO_2 monitor was used to detect CO_2 in the returned endotracheal tube gas. Proper tube position was ultimately assessed using chest radiographs. **Results**: 933 patient intubations were analyzed. We found that 915 of 925 successful intubations had CO_2 present (sensitivity of 99%), 8 of 8 unsuccessful intubations had CO_2 absent (specificity of 100%), 915 of 915 with CO_2 present were successfully intubated (positive predictive value of 100%), and 8 of 18 with CO_2 absent were unsuccessfully intubated (negative predictive value of 45%). Of the 10 successful intubations that did not result in endotracheal CO_2, 7 were thought to have little or no CO_2 in the lung due to poor cardiopulmonary perfusion, 1 had a faulty CO_2 analyzer, and 2 had no explanation for lack of CO_2. **Conclusion**. Although no one sign is completely conclusive for verification of endotracheal tube placement, CO_2 detection is quick and easy and the presence of CO_2 confirms proper intubation. (OF-91-065)

Continuous-Flow Apneic Oxygenation and Ventilation in the Presence of Large Bilateral Bronchopleural Fistulas (BFs)—Robert M Kacmarek PhD RRT, Robert L Goulet MS RRT. Massachusetts General Hospital, *Boston, Massachusetts.*

The presence of a BF during mechanical ventilation usually results in severe $\dot{V}/\dot{Q}$ mismatch and poor gas exchange. We present a case in which hyperventilation was maintained during continuous high flow, although the patient was apneic and bilateral BFs were present. **Summary:** A 54-year-old man (68-in tall, 95 lbs, history of COPD) underwent repair of a large (8.5 x 9.0 cm) pseudoaneurysm of the lower thoracic aorta. During surgery a left-lower-lobe pulmonary tear occurred, requiring 2 chest tubes. When patient was admitted to the ICU, a right pneumothorax was identified requiring placement of 3 chest tubes. Large air leaks were noted from all chest tubes except one of the right-side tubes. Mechanical ventilation was provided by an Emerson ventilator with settings IMV rate 24, delivered V_T 800 mL, exhaled V_T 300 mL, PEEP 0, F_{IO_2} 0.60. ABG values on these settings were P_{O_2} 83, P_{CO_2} 20, pH 7.61. V_T was decreased to correct the alkalosis, with no effect, and PEEP added to prevent atelectasis. Eventually the IMV rate was set at 0 with baseline pressure of 9-12 cm H_2O, F_{IO_2} 0. 65. At this point, the patient was apneic with the ABG P_{O_2} 101, P_{CO_2} 21, pH 7.57. Gas flow exiting the bilateral chest tubes totalled 15 L/min. Continuous flow was maintained for 3 days with no significant spontaneous respirations, after which the volume of the leaks decreased, P_{CO_2} increased, and spontaneous respirations resumed. This patient was ultimately weaned from ventilatory support and sent home. **Significance:** The ability to maintain gas exchange during continuous gas flow with elevated baseline pressure in the presence of apnea was the result of 'one-way' ventilation via bilateral BF in the absence of severe parenchymal lung disease. (OF-91-094)

A Simplified Method for Monitoring Venous Admixture in Humans with Severe Hypoxic Respiratory Failure—John M Graybeal CRTT, Garfield B Russell MD, Michael T Snider MD PhD. The Milton S Hershey Medical Center, *Hershey, Pennsylvania.*

Introduction: Serial measurements of venous admixture ($\dot{Q}_S/\dot{Q}_T$) are often used to monitor the clinical course of hypoxic respiratory failure, as seen in adult respiratory distress syndrome (ARDS). The determination of $\dot{Q}_S/\dot{Q}_T$ uses simultaneous arterial and mixed venous blood gas measurements and is calculated with the equation, $\dot{Q}_S/\dot{Q}_T = (C_{cO_2} - C_{aO_2}/C_{cO_2} - C_{\bar{v}O_2})$, utilizing oxygen contents of pulmonary capillary, systemic arterial, and mixed venous blood, respectively. The ventilation-perfusion index ($VQI = 100 - S_{aO_2}/100 - S_{\bar{v}O_2}$), utilizing oxygen saturations of arterial and mixed venous blood, respectively, has been advocated as a simplified, immediate, and less expensive method of monitoring $\dot{Q}_S/\dot{Q}_T$. Previous clinical comparisons of VQI and $\dot{Q}_S/\dot{Q}_T$ have been made when $\dot{Q}_S/\dot{Q}_T$ has been ≤ 45%. **Question:** Does VQI reliably assess $\dot{Q}_S/\dot{Q}_T$, particularly in the range 45-100%, as seen in patients with severe hypoxic respiratory failure as with ARDS? **Methods:** With approval of the Clinical Investigations Committee, 12 adult patients (5 male), mean (SD) age 25 (7) y, were studied, and 370 comparisons of calculated $\dot{Q}_S/\dot{Q}_T$ and VQI values made. All patients had severe ARDS; 11 required either ECMO or experimental use of intravenous oxygenation for respiratory support. Blood

gases were sampled as clinically indicated and measurements made utilizing both an IL-1323 Blood Gas Analyzer and an IL-282 CO-oximeter. $\dot{Q}s/\dot{Q}t$ was calculated by the clinical laboratory computer using the classic equation. Comparisons were made over wide ranges of $\dot{Q}s/\dot{Q}t$ (8-100%), of F_{IO_2} (0.21-1.0), of PEEP (5-30 cm H_2O), of S_{aO_2} (65-99%), of $S_{\bar{v}O_2}$ (35-92%), of hemoglobin (6.6-14.9 g%), and of P_{aCO_2} (23-74 torr). VQI and $\dot{Q}s/\dot{Q}t$ correlation was determined by linear regression. A p value < 0.05 was considered significant. Bias and standard deviation of the differences (SDD) were also calculated. **Results:** The frequency distribution of calculated $\dot{Q}s/\dot{Q}t$ was < 15% (18), 15-30% (81), 30-45% (103), 45-60% (44), 60-75% (33), and > 75% (91). $\dot{Q}s/\dot{Q}t$ was above 60% in 124/370 comparisons. There was a strong correlation (r = 0.973, p < 0.001, slope = 1.072, Y intercept = -8.4) over the range of VQI and $\dot{Q}s/\dot{Q}t$ values measured. Overall, calculated bias was 4.7 (7.6 SDD) %. The bias was calculated within each $\dot{Q}s/\dot{Q}t$ range. The largest (8.7 ± 7.0 %) and smallest (0.4 ± 5.4 %) bias occurred in the $\dot{Q}s/\dot{Q}t$ range of 30-45% and > 75%, respectively. Changes in VQI correctly predicted changes in $\dot{Q}s/\dot{Q}t$ in 88% of measurements. The incorrectly predicted changes were evenly distributed: 5.9% false predictions of deterioration and 6.1% false predictions of improvement. **Conclusions:** In patients with severe ARDS, there was a high correlation between VQI and $\dot{Q}s/\dot{Q}t$ over a wide range of $\dot{Q}s/\dot{Q}t$ values. Maximal bias was found in the 30-45% $\dot{Q}s/\dot{Q}t$ range. The direction of $\dot{Q}s/\dot{Q}t$ changes was correctly predicted in 88% of comparisons. VQI can provide rapid and (if the correlation extends to saturation measurements utilizing pulse oximetry and fiberoptic $S_{\bar{v}O_2}$ monitoring) continuous as-sessment over a wide $\dot{Q}s/\dot{Q}t$ range. Clinical use of VQI should be made with the understanding that variations in correlation and predictability of $\dot{Q}s/\dot{Q}t$ changes do occur. (OF-91-145)

Alveolar Distending Pressures and Lung Volumes with 4 Different Deep-Breathing Exercises—Harald Mang MD, Massachusetts General Hospital, *Boston, Massachusetts;* Albert Jaegers MD, Max Kirm se, Inst F Anaesthesiologie, *Erlangen, Germany.*

Introduction: Different respiratory maneuvers have been recommended to prevent postoperative pulmonary complications by increasing alveolar distending pressure and lung volume. Theoretically, the highest transpulmonary pressure (TPP) should result in the greatest increase in lung volume. We compared the inspiratory capacities (IC) and the maximum TPP during voluntary deep breathing (VDB), dead-space rebreathing (DSR, 5 mL/kg), incentive spirometry (IS, Voldyne 2500), and intermittent positive pressure breathing (IPPB, 10 or 20 cm H_2O) in 5 patients after partial hepatectomy. **Methods:** Patients who had given informed consent were taught VDB, DSR, IS, and IPPB preoperatively by a physiotherapist blind to the study intent. Directed by the same therapist, they performed these respiratory maneuvers in random order on the first postoperative day while measurements were done by one of the authors. TPP was calculated from airway pressure measured at the mouthpiece and pleural pressure estimated with an esophageal balloon attached to the nasogastric tube. Volume was derived from flow measured with a pneumotachograph. IC is expressed as percentage of forced vital capacity (FVC) measured postoperatively. Values are mean (SD). Statistical analysis was performed with repeated-measures ANOVA (*α < 0.05). **Results:** Only IPPB resulted in TPP and IC significantly greater than voluntary deep breaths.

	VDB	DSR	IS	IPPB
TPP (kPa)	0.6 (0.2)	0.6 (0.3)	0.8 (0.5)	1.1 (0.6)*
IC (%FVC)	69 (21)	78 (20)	82 (18)	147 (45)*

*See text.

Conclusions: In patients at high risk for postoperative pulmonary complications, only IPPB results in alveolar distending pressures and lung volumes significantly higher than occurring with voluntary deep breathing. (OF-91-093)

A Bedside Comparison of Work of Breathing Using T-Piece vs Ventilator CPAP—Dorisanne D Miller RRT, Herbert Patrick MD, Thomas Jefferson University; Sandra B Weibel MD, Julie McCann MD, Thomas Jefferson University Hospital—*Philadelphia, Pennsylvania.*

Introduction: The majority of comparative studies done to determine the weaning mode associated with the lowest inspiratory work of breathing (WOBi) have used the test lung model. We developed a protocol for bedside assessment of WOBi and inspiratory power (Pi) normalized for V_T ($WOBi/V_T$ and Pi/V_T, respectively), using ALFA (Adult Lung Function Analyzer, Medical Associated Services Inc, Hatfield Pa) and chose to compare $WOBi/V_T$ and Pi/V_T for T-piece CPAP with and without the influence of continuous flow (CF). **Method:** 8 ICU patients were studied during medically indicated weaning trials. Each wean method was jointly selected by a respiratory care practitioner and physician blinded to the study. 5 patients using Bear 5 ventilators were placed on CPAP of 0 and 5, and CF was varied from 0-40 L/min in increments of 10-20 L/min; 3 patients using Bear 3 ventilators were placed on CPAP of 0, and CPAP of 5. For all patients, a T-piece trial was performed in a random order with the CPAP trials. During 3 min at each setting, ALFA continuously measured and recorded flow, proximal Y pressure, and distal endotracheal/tracheostomy tube pressure. Breaths selected and manually verified were used by ALFA to compute V_T, f, and $WOBi/V_T$ (using the area within the inspiratory volume distal pressure loops normalized for V_T) and Pi/V_T ($WOBi/V_T$ x f). A comparison of parameters was considered significant for p < 0.05, ANOVA and rank sum tests. **Results:** Data are mean (SEM).

	Pi/V_T, kg · cm/min/V_T			
	T-Piece	CPAP 0	CPAP 5	Optimum CF @ L/min
Bear 5				
1	274.8 (4.5)*	368.0 (10.9)	ND†	286.1 (6.1) @ 40
2	174.5 (16.3)*	296.5 (11.6)	250.5 (9.9)	224.0 (10.8) @ 20
3	119.9 (4.8)*	136.0 (5.0)	184.7 (4.9)	189.2 (4.6) @ 30
4	118.9 (3.5)*	209.5 (16.6)	ND	156.6 (2.3) @ 20
5	139.6 (3.8)	185.5 (4.8)	144.1 (2.5)	110.0 (3.7) @ 10*

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	Pi/V_T, kg · cm/min/V_T			
	T-Piece	CPAP 0	CPAP 5	Optimum CF @ L/min
Bear 3				
6	212.6 (3.7)*	235.6 (3.0)	309.3 (4.0)	NA
7	349.4 (12.1)	300.2 (28.9)	238.5 (9.9)*	NA
8	137.3 (9.7)*	ND	243.8 (4.9)	NA

*Optimized Pi/V_T.
†ND = not done; NA = not applicable.

Conclusions: We conclude that (1) the lowest Pi/V_Ts were obtained on T-piece in 6/8 patients, 4/5 on Bear 5 despite CF and 2/3 on Bear 3; (2) higher CF failed to uniformly reduce Pi/V_T in the manner we expected, requiring an individualized optimum CF setting; and (3) ALFA, by providing a convenient bedside assessment system for $WOBi/V_T$ and Pi/V_T, should enable respiratory care practitioners to minimize Pi/V_T by identifying the optimal weaning mode on a case-by-case basis. (OF-91-132)

P_{aCO_2} Changes Are Inaccurately Predicted by P_{etCO_2} Changes in Critical Care Patients—John M Graybeal CRTT, Garfield B Russell MD, The Milton S Hershey Medical Center, *Hershey, Pennsylvania.*

Introduction: Capnometry offers a continuous monitor of end-tidal carbon dioxide (P_{etCO_2}) that is thought to predict arterial carbon dioxide tensions (P_{aCO_2}) and may be useful in adjusting mechanical ventilation. If P_{etCO_2} monitoring is to be clinically useful, changes in P_{etCO_2} must accurately reflect changes in P_{aCO_2}. **Question:** Are changes in P_{aCO_2} predicted by changes in P_{etCO_2} during ventilatory support of surgical critical care patients? **Methods:** Following Clinical Investigation Committee approval, 80 patients (mean [SD] age = 60.9 [12.8] y) admitted to our SICU for a variety of problems (including MVA, gunshot wound, traumatic amputation, closed head injury, intracranial hematoma, CABG, and cardiac valve replacement surgery) were studied. All patients were clinically stable receiving mechanical ventilation and had a radial artery catheter placed. A mainstream infrared capnometer (Hewlett Packard 78520A) measured P_{etCO_2}. Arterial blood gas samples were obtained as clinically indicated and analyzed for pH, P_{aCO_2}, and P_{aO_2}. P_{aCO_2} values were corrected for body temperature. P_{etCO_2} was recorded when arterial blood was obtained. Linear regression analysis compared the P_{aCO_2} and P_{etCO_2} pairs. A p value < 0.05 was considered significant. Changes in both P_{aCO_2} and P_{etCO_2} compared with the previous sample were calculated and divided into 2 groups, those in which both P_{aCO_2} and P_{etCO_2} changed in the same direction showing agreement (Group 1) and those in which the P_{aCO_2} and the P_{etCO_2} changed in opposite directions showing disagreement (Group 2). $P_{(a\text{-}et)CO_2}$ was calculated for each sample. **Results:** 692 P_{aCO_2} and P_{etCO_2} pairs were obtained. There was a significant correlation between P_{aCO_2} and P_{etCO_2}, $r = 0.523$, $p < 0.001$. The slope of the regression line was 0.51 with a Y intercept of 10.6 torr. Despite this correlation, there was disagreement in the direction of change (Group 2) between the changes in P_{aCO_2} and P_{etCO_2} in 192 (31.3%). 84 occurred with increases in P_{etCO_2} and decreases in P_{aCO_2}, while 108 occurred with P_{etCO_2} decreases and P_{aCO_2} increases. The mean (SD) $P_{(a\text{-}et)CO_2}$ was 8.2 (7.7) torr. **Conclusions:** P_{etCO_2} demonstrates a significant correlation with simultaneous P_{aCO_2} measurements, although the slope of 0.51 indicates that as P_{aCO_2} increases there is a trend towards underestimation by the P_{etCO_2}. Several physiologic factors, common in the critically ill, including increased dead-space ventilation and ventilation and perfusion abnormalities—as reflected by the $P_{(a\text{-}et)CO_2}$ exceeding the 4.7 [2.5] torr value reported in healthy subjects—may account for this. The high number of inaccurate predictions calls into question use of P_{etCO_2} monitoring to replace routine measurement of P_{aCO_2} in SICU patients. (OF-91-136)

Airway Foreign Body Removal with CPT: A Potentially Superior Method to Fiberoptic Bronchoscopy—Karen J Crogan RRT, Ronald E Campbell RRT, Harborview Medical Center; Richard B Goodman MD, University of Washington—*Seattle, Washington.*

Foreign body aspiration is uncommon in adults. Immediate removal is indicated, particularly when the aspirated substance physically obstructs the airway, or when the aspirated substance is caustic to the airway mucosa leading to edema and eventual obstruction or scar formation with permanent airway narrowing (cicatrization). Bronchoscopy (fiberoptic or rigid) is considered the treatment of choice in most cases. We report a case in which CPT was superior to bronchoscopy in the removal of an airway foreign body. A 52-year-old woman presented 8 h after aspirating her morning calcium carbonate tablets. The initially violent episode of coughing had subsided, and she was left with minimal symptoms of intermittent cough and mild dyspnea on exertion. Physical examination revealed asymmetric breath sounds, with a decrease in the right posterior base. Because calcium compounds are radiopaque, the tablets were visible on chest x-ray and were noted to be lodged in the bronchus intermedius. Calcium carbonate is an alkaline substance. A tablet in the airway would be slowly hydrated and the local airway mucosa continuously exposed to this caustic substance. Although there was no atelectasis at the time of x-ray, the potential for further mucosal edema and eventual obstruction dictated immediate removal. Nebulized saline was administered to induce cough, followed by CPT to the right lower lobe. Within 10 min the patient expectorated the 2 tablets. The tablets were semi-solid and friable. Retrieval by fiberoptic bronchoscopy would have been difficult because of the physical nature of the tablets. Saline washings via the bronchoscope would have contaminated the distal airways with alkali and potentially caused further injury. The use of CPT in this patient was, therefore, probably the most effective method of removal. In addition, it imposed less risk, expense, and discomfort to the patient, and allowed her to immediately return to work. Thus, CPT can be superior to bronchoscopy and should always be considered in airway foreign body removal. (OF-91-074)

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Long-Term and Chronic Care

Is nBiPAP Superior to nCPAP in Obstructive Sleep Apnea (OSA)?: Case Report—Edward Barber MA RRT, Neil Shore MD. Salem Hospital, *Salem, Massachusetts.*

The efficacy of nCPAP in the treatment of OSA is well documented. nBiPAP allows for independent settings of inspiratory and expiratory pressures and has recently been reported to achieve comparable therapeutic results at lower EPAP levels, conceivably thereby mitigating or reducing adverse side effects associated with nCPAP therapy and improving compliance. We observed a 41-year-old obese man with episodic breathing and frequent arousals during sleep. He was initially treated with nCPAP via SleepEasy III (Respironics, Murrysville PA), which was effective at 17 cm H_2O but discontinued by the patient as intolerable. He was subsequently treated with nBiPAP via BiPAP ST (Respironics) at inspiratory/expiratory levels of 10/5 cm H_2O. This proved both effective and tolerable. We report on the polysomnographic (PSG) data of 3 tests over a 5-mo period during which the patient had an 8% weight loss but no diuresis or change in medication. PSG tests were done in standard fashion with monitoring of EEG, EOG, EMG, ECG, airflow, and oximetry.

	Baseline	nCPAP	nBiPAP
% Stage 1	28	8	3
% Stage 2	61	32	20
% Stage 3	0	18	19
% REM	11	42	58
Apnea Count	350	0	0
Hypopnea (H)* Count	236	32	0
Resp Disturbance IX (RDI)	86.2	8.2	0
% Time $S_{aO_2} > 90\%$	21	100	100

*H is a waveform 20-50% of baseline; RDI is average hourly occurrences of apnea and/or hypopnea.

In this patient BiPAP was superior to nCPAP in promoting restorative sleep and eliminating respiratory disturbances at a significantly lower EPAP. A trial of nBiPAP may be warranted when high levels of nCPAP are required with OSA patients. Further research is needed with a large number of patients to determine efficacy of using nBiPAP as an alternative to nCPAP. (OF-91-014)

The Short-Term Effects of Inspiratory Muscle Training in Stable COPD Patients—Ann M Wilson RRT, Michael T Kochansky RPFT, Barbara S Shultz CRTT, Dean Hess MEd RRT. York Hospital, *York, Pennsylvania.*

Inspiratory muscle fatigue has been shown to be a contributing factor to exercise limitation in patients with COPD. High inspiratory muscle loads and inspiratory muscle weakness have also been shown to produce hypercapnia in COPD patients. We prospectively evaluated the short-term effects of inspiratory muscle training (IMT) on muscle strength and endurance in a stable group of COPD patients. **Method:** 12 volunteers who completed our 6-wk outpatient pulmonary rehabilitation program were treated using a Threshold Inspiratory Muscle Trainer (HealthScan) at 30% of their maximum inspiratory pressure (MIP) for a period of 6 wk. Once-daily training times ranged from 5-15 min at the beginning of the program (Weeks 1 and 2), and were increased to 30 min daily at the end of the program (Weeks 5 and 6). Baseline measurements of spirometry, 6- and 12-min-walk distance, resting MIP, and MIP following the 12-min walk were performed, and repeated after 2 wk and 6 wk of training. **Results:** A statistically significant increase occurred in resting MIP ($p < 0.001$) and MIP following the 12-min walk ($p = 0.045$). Mean (SD) values for resting MIP were 53.50 (18.12) cm H_2O (baseline), 63.92 (23.43) cm H_2O (2 wk), and 69.75 (24.00) cm H_2O (6 wk). Mean (SD) values for MIP following the 12-min walk were 47.56 (16.03) cm H_2O (baseline), 56.44 (15.39) cm H_2O (2 wk), and 61.11 (24.13) cm H_2O (6 wk). Pulmonary function values (FVC, FEV_1, and peak flow) showed no change ($p = 0.89$ for FVC, $p = 0.79$ for FEV_1, and $p = 0.79$ for peak flow). The mean (SD) 6-min-walk distances (in ft) at baseline, 2 wk, and 6 wk, respectively, were 1094.82 (321.77), 1143.55 (348.84), and 1160.73 (371.00) ($p = 0.05$). The 12-min-walk distances were 2238.36 (666.43), 2295.27 (748.05), and 2304.00 (786.61) ($p = 0.476$) at baseline, 2 wk, and 6 wk, respectively. **Conclusions:** Our data suggest that use of a threshold-type inspiratory muscle trainer may increase inspiratory muscle strength in stable COPD patients. Although MIP increased both at rest and following a 12-min walk, and there were increases in 6-min and 12-min-walk distances, this group of patients still exhibited a decline in muscle strength following exercise periods. This reduction in MIP following sustained activity was similar to their pre-training decline. However, the overall improvement in both resting MIP and post-walk MIP following inspiratory muscle training may increase patient tolerance of both short-burst and sustained periods of activity. Further work is needed to evaluate the long-term effects of inspiratory muscle training. (OF-91-062)

Efficacy of Pneumatic Demand Delivery of Oxygen during Inspiration—Barry Make MD, Steve Senn. National Jewish Center for Immunology & Respiratory Medicine, *Denver, Colorado.*

Devices that deliver O_2 during the inspiratory portion of the respiratory cycle achieve similar oxygenation and reduce O_2 usage compared to continuous flow. We evaluated a new pneumatic demand device (PDD) that delivers O_2 only during inspiration. The PDD initiates delivery of a fixed 12-mL bolus of O_2 when nasal pressure falls below -0.05 cm H_2O and continues to deliver O_2 at the desired continuous flowrate during the remainder of inspiration until nasal pressure rises above -0.05 cm H_2O. Oxygen is delivered via dual-lumen tubing and controlled pneumatically, eliminating the need for a battery. To evaluate the PDD, we studied 8 patients with COPD and 4 with interstitial lung disease (ILD) who had been using O_2 as outpatients based upon physician prescription. Data

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shown are mean (SE). The COPD patients were 66.6 (3.0) y with FEV_1 0.76 (0.10) L, 29 (4) %predicted; and total lung capacity (TLC) 7.52 (0.70) L, 141 (10) %predicted. ILD patients were 44.5 (11.7) y with a TLC of 4.70 (1.18) L, 80 (14) %predicted. Patients breathed O_2 at 1, 2, or 3 L/min at rest, and at 2, 3, or 4 L/min while pedaling a stationary bicycle at 30% of maximum work load. The order of flowrates was randomized. Blood gases were sampled via indwelling arterial line. Using a repeated measures analysis of variance to analyze the difference in P_{aO_2} with PDD and continuous flow, there were no significant differences in responses for the two disease groups ($p = 0.30$ for rest and $p = 0.83$ for exercise) or across flowrates for the two disease groups during rest ($p = 0.42$) and exercise ($p = 0.83$). P_{aO_2} with PDD was higher at rest, 80.2 (2.4) torr with PDD and 77.9 (2.4) torr with continuous flow ($p = 0.0007$), due to a higher P_{aO_2} at 1 L/min using PDD, 80.2 (5.3) torr with PDD and 69.2 (4.0) torr with continuous. P_{aO_2} with PDD at exercise was marginally higher, 72.8 (2.6) torr with PDD and 71.2 (2.5) torr with continuous ($p = 0.055$) due to a higher P_{aO_2} at 2 L/min using PDD, 67.2 (3.9) torr with PDD and 62.8 (3.4) torr with continuous. PDD use resulted in a 48.6 (1.4) % savings of oxygen. PDD was well tolerated, and only 1 patient was able to detect a difference between PDD and continuous flow. We conclude that use of pneumatically controlled oxygen delivery during inspiration results in similar or better oxygenation compared to continuous flow in patients with COPD and ILD at rest and exercise and that it can significantly reduce oxygen usage. (Supported by Puritan-Bennett Corp.) (OF-91-106)

Sternocleidomastoid EMG Activity during the Application of BiPAP—Martin C Wilkins BS RRT, Gregory Flick MD, St Vincent Hospital & Medical Center; MaryBeth Cruz BS RPsgT, Sleep Physiology Services—*Portland, Oregon.*

Introduction: Mask ventilation with BiPAP holds promise as a method of muscle rest in patients with advanced COPD. Sternocleidomastoid (SCM) electromyographic (EMG) activity has been shown to correlate with muscle work in patients who use accessory muscles; experience suggests muscle work may increase during respiratory assistance with mechanical ventilation if not titrated appropriately. We therefore elected to study sternocleidomastoid EMG activity during the application of BiPAP to determine whether muscle activity could be suppressed with appropriate BiPAP levels. **Method:** 10 patients with advanced COPD were chosen for study. Each patient demonstrated spontaneous use of accessory muscles on physical exam. Raw SCM activity was recorded to computer disk, and time averaged over 300-ms intervals. BiPAP was administered with an appropriately fitting nasal mask attached to a Respironics Spontaneous BiPAP unit. The studies commenced at 11:00 PM (±1 h) and duration of sleep titration was 6 h (±1.5 h). BiPAP was increased until a sharp reduction or an absence in SCM EMG activity was noted or until disorganized muscle activity occurred, at which point BiPAP levels were decreased. **Results:** 2 patients demonstrated intolerance to the BiPAP mask or circuit and had no reduction in SCM activity. 4 patients were successfully titrated to absent SCM activity and 4 others demonstrated marked reduction in SCM activity. **Conclusion:** We conclude BiPAP can be utilized to reduce accessory-muscle EMG activity and thus holds promise as a method to reduce work of breathing in patients with advanced COPD. (OF-91-157)

HFJV via a SCOOP Trach: A Case Report—Greg Foust RRT, Michael D Wilons MD. Baptist Memorial Hospital, *Memphis, Tennessee.*

Since transtracheal O_2 therapy provides a more cosmetically pleasing, as well as cost-effective and convenient means of providing supplemental O_2 to patients who are chronically O_2 dependent, this modality's popularity is on the rise. Concurrently, HFJV is a mode of ventilation that has enjoyed some utility in very specific situations. For those who have had experience with both, a logical question would be, can HFJV be used to manage acute exacerbations of COPD? Note the following: A 60-year-old white woman with O_2-dependent COPD was admitted to our hospital with an exacerbation. Since a significant fibrotic component existed to her disease, oxygenation was often difficult even when binasal O_2 was employed simultaneously with O_2 via her SCOOP trach. On this particular admission, she presented to the Emergency Department in respiratory distress. She then had a hypoxic siezure (P_{aO_2} 18 torr, pH 7.37, and P_{aCO_2} 53 torr) and lost consciousness. A 2 L/min binasal cannula was added to the 2 L/min via the SCOOP. Subsequent ABG revealed pH 7.28, P_{CO_2} 58 torr, and P_{O_2} 19 torr. Because of the acidotic trend and the persistent hypoxemia, HFJV was initiated at 10 psi driving pressure, 100 breaths/min, 30% t_i, and 100% O_2. Within minutes she regained consciousness, and ABG revealed a P_{aO_2} in the 70s. After 2 hours of HFJV, discontinuance was tolerated well. Since this initial experience and discharge, she has been ventilated with HFJV on one other occasion. Approximately 2 mo later, during an admission for an acute infection, she was ventilated for just a few hours to resolve an acute hypoxemic episode ($P_{aO_2} < 30$ torr). Catheter motion and potential mucosal damage were considerations, but presented no problem in this patient. This patient's problem was primarily hypoxemia. After the initial 2 hours of HFJV during this second admission, 2 1-h treatments were performed the next morning. Each episode of HFJV seemed to enhance the mobilization of secretions. It would be interesting to note whether this type of intervention would be as successful in exacerbations where CO_2 retention was more of a problem or could intermittent treatment with HFJV prevent or decrease the severity and/or frequency of such exacerbations. (OF-91-116)

ThAIRapy Vest vs Conventional Chest Physical Therapy (CPT): Case Report—Kemberley K Hull CRTT, Robert H Warren MD. Arkansas Children's Hospital, *Little Rock, Arkansas.*

A new chest percussion device known as the ThAIRapy Vest (TV) was compared to conventional CPT in the treatment of an

adult with severe cystic fibrosis (CF). The TV is an inflatable vest linked to an air-pulse delivery system by flexible hoses and is used in a sitting position. The system pulsates against all areas of the chest, rhythmically mobilizing mucus. **Case Summary:** A 32-year-old man with end-stage CF was admitted for an acute pulmonary exacerbation complicated by congestive heart failure. Initial therapy included I.V. antibiotics, aerosol, and manual CPT to all lobes qid. CPT resulted in no sputum production in this patient. O_2 therapy was 2 L/min via nasal cannula. On Day 26, the TV became available and was substituted for CPT for 30 min qid to evaluate its efficacy. All other therapy remained unchanged. Therapy with TV resulted in the production of large amounts of sputum. Changes in pulmonary function data occurred as follows:

	FVC (L)	FEV_1 (L)	PEF (L/s)	FEF_{50} (L/s)	S_{pO_2} %	O_2 (L/min)
Predicted	5.54	4.59	9.9	5.67		
Pre-Hosp	1.45	0.59	2.8	0.15	70	2
Day 27	1.37	0.70	2.5	0.31	91	1
Day 30	1.71	0.87	3.5	0.21	94	1

Subjectively the patient felt better and was discharged on Day 30. **Conclusion**: In this patient, the TV was initiated as a single therapy change with good subjective and objective results. Specifically, sputum production occurred when conventional CPT had not been effective in mobilizing secretions. Further study is needed to assess the efficacy of the TV in improving bronchial drainage in CF patients. (OF-91-010)

Successful Home Mechanical Ventilation: Results of a National Survey—Karen A Glenn RRT, Barry Make MD, National Jewish Center for Immunology & Respiratory Medicine, *Denver, Colorado.*

To determine the feasibility of home mechanical ventilation, a national survey was conducted by the National Center for Home Ventilation. The Center is an independent research group supported by professional organizations and funded by the home health care industry. A national database of patients receiving positive-pressure ventilation in the home was established from data provided by respiratory therapists employed by home-care vendors. Therapists were asked to complete a questionnaire on patient age, diagnosis, ventilator use, duration of home care, and use of home health personnel. The first 100 patients reported to the Center reside in 17 different states and form the basis for this report; 17 patients are children (< 13 years of age) and 83 are adults. The most common diagnoses requiring home ventilation are neuromuscular disorders, which are present in 11 children (65%) and 49 adults (59%). The other 6 children have bronchopulmonary dysplasia. 16 adults (19%) have chest-wall disorders, and 13 (16%) have obstructive airway diseases. Patients use their ventilators for 17.7 (0.7) mean (SE) days daily. 51 of the patients require mechanical ventilation continuously 24 h/d. 16 patients (10 children, 59%, and 6 adults, 7%) use 5.2 (0.3) cm H_2O PEEP, and 59 patients require supplemental O_2. 56 patients have a second ventilator. The length of time at home is 33.7 (3.9) mo; 77/100 have been at home for ≥ 1 year and 20 have been at home for ≥ 4 years. 54 patients (54%) do not use paid health-care personnel on a daily basis. This national survey of home ventilation documents that despite significant respiratory care needs, ventilator-assisted individuals are living at home for long periods of time, and many patients and families are self-sufficient without the need for extensive assistance from paid caregivers. Continuing data collection using this cooperative model among members of the home health care community can provide additional important information about home ventilation. (Supported by grants from Aequitron, Allen & Hanburys Division of Glaxo, Americare Home Health Care, Ballard Medical Products, Baxter Healthcare, Clasen Home Health Care, Cryogenic Associates, Glasrock Home Health Care, Homedco, Hudson Oxygen, Instrumentation Industries, Lifecare, Lincare, Prime Care Medical, Puritan-Bennett, Respironics, Schering, Siemens, SmithKline Beecham, and The Pediatric Professionals.) (OF-91-105)

Transtracheal BiPAP as an Invasive Method of Augmented Ventilatory Support—D Theron Van Hooser MEd RRT, Kent Christopher RRT MD, Vencor Institute for Oxygen Therapy; David Brown BA RRT, Jim Bowman RRT, Susan Jorgen RN MSN, Vencor Hospital—*Denver, Colorado.*

BiPAP™ (Respironics, Murrysville PA) is a flow- or time-cycled assistor device that delivers 2 pressures. BiPAP has been viewed as analogous to pressure support with PEEP. Review of the literature shows that BiPAP is safe and effective when used with a nasal mask for augmented ventilation. This case series reports the use of BiPAP via tracheostomy to augment ventilation in 3 patients with chronic respiratory failure and hypoxemia. 2 patients (1 with restrictive lung disease and 1 with COPD) were successfully weaned from full mechanical ventilatory support but needed augmented (nocturnal) support. The third had bullous emphysema with scarring and fibrosis from tuberculosis and had been using nasal BiPAP continuously for 2 mo prior. Using a modified circuit with added humidity, we administered BiPAP invasively via tracheostomy tube to all 3 patients. During the daytime, 2 patients were maintained on low-flow O_2 only. All patients tolerated the mode well. BiPAP pressure settings were selected according to the last pressure-support and PEEP values on the conventional ventilator. Changes were then made according to ABG analysis and other clinical assessment. O_2 flowrates (both via the BiPAP device and TTC) were selected to keep $S_{pO_2} > 90\%$. We adapted the BiPAP circuit using a servo-controlled, heated humidifier (Marquest 3000), a heated-wire circuit (Marquest # 542031), and the Respironics "whisper valve" attached directly to a tapered flex tube and swivel. A Lifecare pressure alarm (23001) was used to monitor "disconnects" and delivered pressures. We selected the BiPAP S/T-D to deliver augmented support because it is easier, simpler, and less costly than a standard volume-cycled home ventilator, and total ventilatory support was not needed. The 2 patients remaining on BiPAP

continue to use it nocturnally in the home and have had no problems during the 3 mo since. We conclude that BiPAP (applied invasively and with proper humidification) is a simple, effective mode of augmented ventilatory support for selected patients who do not require total ventilatory support. (OF-91-123)

Techniques and Devices for Patient Education

Use of the Aerosol Inhalation Monitor (AIM) vs Conventional Instruction in Teaching Metered Dose Inhaler (MDI) Techinque to Normal Subjects—Tarilyn S Dobey MEd RRT, Bethene Gregg MS RRT, Barbara Ludwig MA RRT. University of Kansas Medical Center, *Kansas City, Kansas.*

Poor technique is a common problem with MDI use. Errors include inappropriate actuation, failure to inspire slowly and deeply, and failure to perform a 5-s breath-hold after inspiration. Since poor technique can significantly reduce the effectiveness of drugs delivered via MDIs, an alpha study was performed to determine if use of the AIM (Vitalograph, Lenexa KS) during MDI instruction improved MDI technique in normal subjects with no prior experience with inhalers. **Method:** 50 normal subjects were randomly divided into 2 groups to compare conventional instruction (CI) in MDI use with instruction produced by the AIM. The AIM is a small desk-top instrument that allows an instructor to monitor the patient's coordination and performance when using an MDI. Inhalations in the CI group were monitored by the AIM without instructor feedback. **Results:** 92% of the subjects in the AIM group successfully performed 2 consecutive correct inhalations. Only 56% of the CI group correctly performed 2 consecutive correct inhalations, although the instructor recorded that 96% had achieved success. The most common error detected by the AIM was inadequate inspiratory flow (< 10 L/min or > 50 L/min). The difference in the number of correctly performed inhalations between the 2 groups was determined and the X^2 statistic calculated (8.419 $p \leq 0.005$, df = 1). **Conclusion:** While the AIM can enhance instruction and improve MDI technique in normal subjects by providing the clinician with important feedback regarding the essentials of MDI technique, further study with COPD patients is warranted. (OF-91-012)

Comparison of Self-Administration Techniques for Bronchodilators Delivered by MDI vs Rotahaler (RH)—M Darnetta Baker MBA RRT, Patricia Silver MEd RRT, Steven D Shapiro MD. Jewish Hospital, *St Louis, Missouri.*

The RCS department compared retention of proper self-administration techniques for MDI vs RH based on 9-step instruction protocols unique to each device. The RH is a plastic device that when turned opens a capsule containing albuterol powder. Subsequent inhalation through a mouthpiece disperses the powder into the airstream. **Method:** Patients were randomized to receive either MDI or RH and evaluated after instruction at 3 24-h intervals (n = 22 RH and n = 31 MDI), with no significant differences between the groups with respect to mean age and medical diagnosis. **Results:**

Evaluation	RH		MDI	
Time	%*	n†	%	n
24 h	54	22	57	31
48 h	73	15	65	2
72 h	80	10	78	18

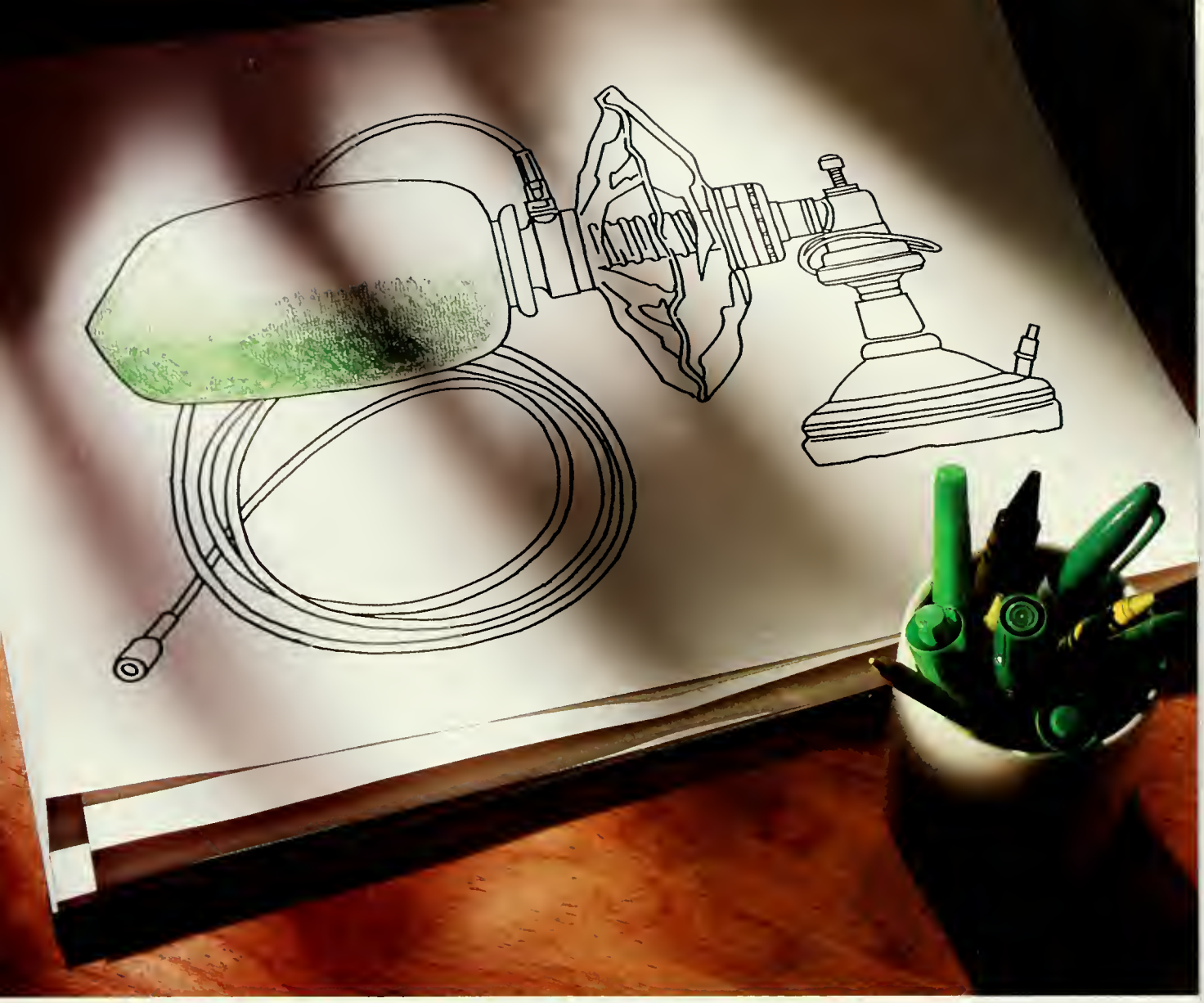
*% = percentage performing 7-9 steps correctly.

†n = number of patients tested.

Steps frequently missed in the MDI group were canister shaking and reservoir position. Capsule insertion and canister position were often performed incorrectly in the RH group. Other steps commonly performed incorrectly by patients in both groups were breath-holding, 2-min wait between puffs, and compliance with ordered dosage. RCS educational material was altered to emphasize proper technique for steps performed incorrectly. **Conclusion:** The data demonstrate no significant difference in the retention level between groups; however, progressive improvement was noted in both groups following instruction. Therefore, despite the higher cost of RH, it may be used as an alternative for patients who cannot tolerate MDI aerosol or master MDI technique. Also, due to environmental concerns associated with MDI, RH is an acceptable long-term alternative method of aerosol delivery. (OF-91-128)

Smoking Beliefs in Coronary Artery Disease Patients—G Wayne Silvers BA, LM Nett RN RRT, TL Petty MD, PSL Center for Health Sciences Education; D Causey MD, ALZA Corporation—*Denver, Colorado.*

Smoking cessation is advised for patients who have coronary artery disease (CAD), yet many persist in smoking after diagnosis. We wished to determine the attitude of smoking patients with CAD regarding smoking and their health, using a questionnaire (Fagerstrom Nicotine Dependency Test [FNDT]) and biologic tests (plasma cotinine, a metabolite of nicotine, and end-expiratory carbon monoxide [CO] levels) related to nicotine dependence. 34 cardiac patients were enrolled in this study by documentation of any of the following: coronary artery bypass surgery or angioplasty, myocardial infarction, angina pectoris with a positive nuclear scan on exercise test, or angiographic evidence of more than 60% obstruction in at least 1 coronary artery. We found that patients who volunteered for this study had a mean age of 55.1 y and currently smoked 29.6 cigarettes/d. These patients had smoked for a mean of 36.1 y. Mean values for the FNDT scores were 8.3, with an end-expiratory CO of 33.6 ppm (non-smoker < 10 ppm) and a serum cotinine level of 197.9 ng/mL (non-smoker < 20 ng/mL) We determined from the questionnaires that a total of 91% wanted to stop smoking for health reasons and had been advised to do so by their physicians. When asked about their current state of health, 44% responded that they have problems and are at risk for some disease, 38% responded that they have no problems but are at risk for some disease, 15% responded



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that they have no problems and are at no risk, and 3% responded that they are not sure. All had made numerous attempts to quit smoking (mean 5.2 attempts). Analysis of serum cotinine and end-expiratory CO levels revealed significant correlation between the 2 ($r = 0.454$, $p = 0.008$). The FNDT scores correlated positively with number of years of smoking ($r = 0.376$, $p = 0.029$). The study demonstrated that most of these patients with CAD are aware that smoking poses a health risk; however, 56% denied that they had health problems, and 18% did not consider themselves at risk for any disease. These patients are defined as heavily addicted by criteria of a score of > 7 on the Fagerstrom test with > 25 cigarettes smoked/d. Further help in smoking cessation is needed for these patients. Cardiac educators and rehabilitation therapists should educate patients that they have a significant illness, and that their prognosis is significantly worsened by continued smoking. We conclude that these patients need outside intervention for help with nicotine addiction. (OF-91-027)

The Use of Respiratory Biofeedback in Respiratory Disease—William Shearouse RRT, Respiratory Associates Inc, *West Palm Beach, Florida.*

Introduction: I sought to determine whether patients suffering from COPD would benefit from respiratory biofeedback (RFB). RFB is accomplished by using an amplifier that feeds the respiratory rhythm to the reticular formation found in the brain. The biofeedback loop starts at the sensor that scans the patient's breathing rhythm. The sensor is connected to an amplifier that converts the electrical impulses into acoustical and visual outputs. These outputs are transferred to the patient by a headpiece, which is made up of an eyeshield with lights and stereo earphones. Outputs increase and decrease in volume and intensity as the patient inhales and exhales. **Method**: 10 patients were treated using the RFb 5000 (RFB Technologies, Boca Raton FL). I measured O_2 saturation (S_{pO_2}) via a Nellcor N-200 before, during, and after treatment. Patients' dyspnea scores (ATS Grade) were evaluated before and after therapy. The patients were given 12 treatments, each lasting 30 min. **Results**: All patients had improvements in both their O_2 saturations and their ATS dyspnea scores. Mean (SD) S_{pO_2} was 90 (2) %, increasing to 95 (2) % post-therapy. The average dyspnea score of 4.5 decreased to 2.5. One patient who had been confined to bed for 3 mo with an O_2 saturation of 88% (on 4 L/min nasal cannula) increased her O_2 saturation to 96% on 2 L/min nasal cannula. Since her therapy, she has been ambulatory with portable O_2. **Conclusion**: The intensity of dyspnea is clearly related to conscious perception of the effort involved in breathing. Dyspnea may arise from the inappropriate relationship between the force of contraction of respiratory muscles and the volume of air exchange. It is my belief that this modality realigns this relationship and decreases the work of breathing. Further studies are warranted. (OF-91-055)

Tracheostomy Speaking Valve in Pediatric Ventilator-Assisted Patients—Ellie Zuck Tucker AS RRT, Benita Rogers CRTT, Angela Jerome RN MSN, Gerald L Strope MD. Children's Hospital of The King's Daughters, *Norfolk, Virginia.*

The Passy-Muir Tracheostomy Speaking Valve was evaluated for use in tracheotomized, ventilator-assisted pediatric patients to improve quality of life by allowing vocalization without compromising respiratory status. The device is a one-way valve that opens on inspiration, allowing gas into the trachea and inflating the lungs. On expiration the valve closes, redirecting gas through the vocal cords and permiting speech. **Method**: 6 tracheotomized, ventilator-assisted pediatric patients ages 15 mo-12 y (58% with lung disease, 42% with neuromuscular disease) on either the LP-6 volume ventilator or Healthdyne Infant pressure ventilator were evaluated for 14 consecutive days. The device was adapted to their tracheostomy tubes & ventilator circuits. Sessions began with baseline (pre-valve) measurements of pulse oximetry, capnography, heart rate, PIP, PEEP, and respiratory and speech assessments. Pressure readings were recorded between the patient's airway and speaking valve on a strip chart. Repeat measurements were made immediately following placement of the valve and for approximately 15 min thereafter. **Results**: Pulse oximetry, capnography, heart rate, and respiratory rate were near baseline. 100% of patients had increased clarity and intensity of vocalization. Nasal flaring was absent, and color remained pink. Increased accessory-muscle use on expiration was noted in patients with lung disease. 4 of 6 patients required intervention before the end of 15 minutes because of breath stacking or increased levels of PEEP. Repositioning, distracting, and encouraging vocalizations alleviated the problem in most instances. 2 of 6 patient studies were discontinued on Day 10 of 14, 1 due to viral illness and 1 secondary to a vagal response and/or mucus plug mobilization. **Conclusion**: Many ventilator-assisted patients are able to speak without assistance by utilizing the air leak around their tracheostomy tubes in conjunction with ventilator breaths. Patients with small and/or positional leaks or neuromuscular weakness may be unable to vocalize, thus any method to improve quality of life by improving the ability to communicate would be beneficial. The Passy-Muir Tracheostomy Speaking Valve enhanced our patients' ability to vocalize; however, breath stacking and increased levels of PEEP warrant that the valve be used on a case-by-case basis and monitored closely. (OF-91-058)

Outcome of a 3-Day Comprehensive Pulmonary Rehabilitation Program—Karen S Flanigan MS RRT, Carl D Mottram RPFT RRT, Robert W Viggiano MD. Mayo Clinic, *Rochester, Minnesota.*

Comprehensive pulmonary rehabilitation programs (PRPs) have been documented to benefit patients with COPD. Traditionally, PRPs are 6-12 weeks in length. However, to address the needs of patients seen at a regional medical center who would be unable to attend a traditional program, a 3-day PRP was developed. The multidisciplinary PRP included educational sessions on lung function and pathophysiology, medications, O_2 therapy, activities of daily living, and exercise ses-

sions with emphasis on upper-extremity resistance training, breathing techniques, and reconditioning on treadmill/bicycle ergometer. Exercise prescriptions were provided: 3-7/wk for 20-30 min at determined target heart rates and perceived exertion of "somewhat hard" (Borg Scale 13). Follow-up interviews were utilized to determine if this abbreviated PRP improved quality of life and motivated compliance with the prescribed exercise program. The population of 72 patients attended the PRP 6-16 months prior to follow-up; 64 (88.9%) completed the telephone survey conducted by a staff member unknown to them. Respondent characteristics were 23 women, 41 men; age range 31-84 y, avg 66.02 y; FEV_1 range 0.39-2.49 L/s, avg 0.86 L/s; FEV_1%pred 12-70%, avg 28.98%. 48% reported increased self-confidence in their ability to perform tasks and activities. Based on responses to multiple questions, 81.3% initiated an exercise program and 53.1% were exercising at the time of follow-up. 46% reported an increased ability to perform physical activity. The initiation and continuation of the prescribed exercise program suggests a high degree of patient motivation. 91.9% felt that overall the PRP was beneficial. In conclusion, a 3-day PRP may provide significant benefits to a referral population. (OF-91-154)

Cardiopulmonary/Critical Care Equipment and Technique Evaluation

Development and Evaluation of a Bronchoscopy Assistant's Cart—Harold B Winnike BS CPFT RCP RRT, Denise McElyea CPFT RCP CRTT. University of Texas Medical Branch, *Galveston, Texas.*

With complete remodeling of our bronchoscopy suite (including installation of a fixed C-arm fluoroscopy unit), it became necessary to devise a cart/workstation for the bronchoscopy assistant to use in a limited workspace; 7 functions were identified as essential in the design of the cart: (1) all equipment needed for procedures within arm's reach; (2) control of O_2 and medication delivery; (3) control of airway management and bronchial hygiene; (4) retrieval and fixation of specimens/biopsies for diagnostic evaluation; (5) utilization of ceiling-mounted compressed gas, vacuum, and electrical lines; (6) maneuverability in a limited space; and (7) capability of carrying monitors and bronchoscope light source. **Methods:** After examining various carts and their configurations, an Eastern Rail Dual-Sided Trauma/ER cart was purchased for use as the basic unit of our bronchoscopy cart. Components were 2 O_2 flowmeters, 1 air flowmeter, 2 vacuum regulators with receptacles, 1 instrument tray, light, and different-sized baskets and compartmental trays. A compact unit capable of noninvasive monitoring of blood pressure, ECG, and S_{pO_2} was purchased (Propaq 102 with Oximeter expansion, Protocol Systems) and mounted with a single swing-arm mount on the cart. The bronchoscope light source was mounted on the cart in a fashion that allows the light guide bundle to pass to the left of the bronchoscopist, within reach for operation and adjustment. The instrument tray was placed at a level to allow the assistant to prepare specimens and biopsies while having a clear view of the monitor, O_2 flowmeters, and vacuum controls. Evaluation of the system was based on the 7 functions stated above. **Results:** Over a 3-mo period, rearrangement of the components enabled us to determine the most effective setup. The monitor was moved to the side of the cart away from the patient, permiting viewing by both the assistant and the bronchoscopist. An extension was needed for the oximeter probe to reach the patient. The ECG cable, oximeter-probe cable, and blood-pressure cuff tubing were grouped together and attached to a rail so as not to interfere with supplies or work area. **Conclusions:** We developed a cart capable of carrying all items necessary for performing bronchoscopy, with the means to control the airway, medication delivery, and specimen retrieval. This cart has worked exceptionally well in our setting. We have found it to be cost-effective and quite useful in our limited work space. We believe it would function and be cost-effective in any hospital performing enough procedures to warrant a dedicated bronchoscopy suite. (OF-91-026)

Improvement to the Deltatrac Metabolic Monitor—F Wayne Johnson RCP RPFT, K Knaus Kinninger RCP RPFT, Kathy Jacobson RCP CCVT, David M Burns MD. UC-San Diego Medical Center, *San Diego, California.*

Introduction: Laboratory validation of $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ by the Deltatrac (Datex Instrumentation, Helsinki, Finland) revealed a sensitivity to V_T when $V_T \geq 1$ L were used in respiratory measurements. Further investigation revealed that the Deltatrac's ability to capture total $\dot{V}_E$ was the source of error and that it occurred only with moderate-to-high-peak airway pressures. We postulated that this phenomenon was a design limitation due to patient gas escaping from the flow-generator inlet during large, forceful expirations. To test our hypothesis we ran the Deltatrac (using manufacturer-recommended setup) in parallel tests, with and without an extension (canopy tube) attached to the flow-generator inlet. **Method:** N_2 and CO_2 were infused into a constructed lung model at known rates to simulate $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$. The infusion of N_2 and CO_2 was kept constant using a series of precision flowmeters (Gilmont, Great Neck NY). Independent F_{IO_2} measurements for calculating predicted $\dot{V}_{O_2}$ were made with a 1100a mass spectrometer (Perkin-Elmer, Pasadena CA). Accuracy of the flow controller system was verified volumetrically before and after each trial by water-sealed spirometer (Godart, Bilthoven, The Netherlands). Mechanical ventilation of the lung model was controlled by a 7200a ventilator with bacterial filter, nondisposable circuit, Cascade I with tower, and 7205 external air/O_2 blender (Puritan-Bennett, Carlsbad CA). The 7200 ventilator was set at CMV f 10; V_T 750, 1000, 1250 mL; $\dot{V}$ 60 L/min; square-wave flow pattern; humidification of inspired gases (35°C). Predicted $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ (300 mL/min) were measured for combinations of $\dot{V}_E$ (7.5, 10, 12.5 L/min) and PIP (40, 53, 67 cm H_2O) with F_{IO_2} (0.21, 0.40, 0.60, 0.80). Each of the trial runs (25 min) was followed by a trial run (25 min) with canopy tube attached to the flow-generator inlet. Mean error of measurement was calculated as measured-predicted and expressed as percentage of predicted value. **Results:** Test

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results for the Deltatrac setup without canopy tube attached had mean errors of $\dot{V}_{O_2}$ -4.0%, -12.5%, -20.8%; and $\dot{V}_{CO_2}$ -1.5%, -9.0%, -17.1% at V_T 750, 1000, 1250 mL, respectively. The Deltatrac with the canopy tube attached to the flow-generator inlet had mean errors of $\dot{V}_{O_2}$ -1.6%, -2.5%, -5.4%; $\dot{V}_{CO_2}$ 0.3%, 1.0%, -0.5% at V_T 750, 1000, 1250 mL, respectively. **Experience:** The flow generator maintains a constant flow of 40 L/min, expiratory flowrates exceeding this level (as generated by high V_T in this model) will cause expiratory gas to flow backwards towards the flow-generator inlet. An air capacitor captures this backwards flow when $V_T \leq 1$ L, allowing the flow generator to draw in the captured gas when the expiratory flowrate drops below 40 L/min. Extending the air capacitor by attaching the canopy tube to the flow-generator inlet facilitates capturing larger V_T and is a logical choice for increasing the range of V_T that can be measured accurately. **Conclusions:** Our tests with and without canopy tube attachment confirmed our hypothesis. We suggest Deltatrac performance can be improved at $V_T \geq 1$ L by attaching the canopy tube to the flow-generator inlet. (OF-91-097)

Validation of Two Metabolic Monitors for Use in Mechanically Ventilated Patients—F Wayne Johnson RCP RPFT, K Knaus Kinninger RCP RPFT, Kathy Jacobson RCP CCVT, David M Burns MD. UC-San Diego Medical Center, *San Diego, California.*

Introduction: The accurate measurement of $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ utilizing expired gas has remained clinically desirable but technically elusive for critically ill patients on mechanical ventilation. We validated 2 metabolic monitors: the P-B 7250 (Puritan-Bennett, Carlsbad CA), a new open-circuit production prototype, and the Deltatrac (Datex, Helsinki, Finland) in laboratory simulations to examine whether changes in PEEP, F_{IO_2}, $\dot{V}_E$, and V_T influence the accurate measurement of $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$. **Method:** N_2 and CO_2 were infused at known rates using precision flowmeters to simulate $\dot{V}_{O_2}$ (< 500 mL/min) and $\dot{V}_{CO_2}$ into a constructed lung model. Accuracy of the flow-controller system was verified volumetrically pre- and post-trial. Independent measurements of F_{IO_2} for calculation of predicted $\dot{V}_{O_2}$ were made with a 1100a mass spectrometer (Perkin-Elmer, Pasadena CA) at the ventilator humidifier's distal outlet. The lung model was mechanically ventilated by a 7200a ventilator with bacterial filter, nondisposable circuit, Cascade I with tower (Puritan-Bennett, Carlsbad CA) using a wall air/O_2 gas source. Measurements of $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ (predicted level of 300 mL/min, STPD) were made with humidification of inspired gases at 35°C for experimental conditions of F_{IO_2}, V_T, PEEP, and $\dot{V}_I$ at PIP (13 to 60 cm H_2O), $\dot{V}$ 60 L/min, and on CMV. **Results:** Mean error of measurement was calculated as measured-predicted and expressed as percentage of the predicted value.

	Mean Error			
	7250		Deltatrac	
with F_{IO_2}	$\dot{V}_{O_2}$	$\dot{V}_{CO_2}$	$\dot{V}_{O_2}$	$\dot{V}_{CO_2}$
0.21	0.6	-2.6	0.9	0.9
0.40	-0.9	-1.4	0.4	0.0
0.60	1.9	-1.3	7.5	0.0
0.80	-2.6	-1.0	-13.5	0.4
with V_T (mL)				
500	-0.1	-2.1	-1.5	0.9
750	-0.2	-1.3	-4.3	0.6
1000	-0.5	-1.4	-8.5	-0.4
with PEEP (cm H_2O)				
0	0.8	-1.0	-3.0	0.1
10	-2.5	-2.9	-3.3	0.6
20	-0.2	-1.3	-10.4	0.6
with $\dot{V}_E$ (L/min)				
7.5	-1.0	-2.3	-1.4	1.0
10	-0.7	-2.6	-3.7	0.7
15	0.5	-0.7	-4.5	0.3
20	0.1	-0.5	11.1	-0.9

Conclusion: Both systems appear to provide stable, reliable, and accurate measurement of $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ over range of F_{IO_2} up to 0.60. The Deltatrac manifested reduced accuracy for measurements of $\dot{V}_{O_2}$ at settings of V_T 1 L, $\dot{V}_E > 15$ L/min, $F_{IO_2} > 0.60$, and PEEP 20 cm H_2O. Measurement of $\dot{V}_{O_2}$ with the 7250 at these settings was accurate. (OF-91-098)

A Simple Method for Providing a Stable F_{IO_2} for Metabolic Measurements during Mechanical Ventilation—F Wayne Johnson RCP RPFT, Nancy Thurman Tendal BS RCP RRT, John Newhart RCP CRTT. UC-San Diego Medical Center, *San Diego, California.*

Introduction: The accurate measurement of F_{IO_2} is essential in the measurement of oxygen consumption ($\dot{V}_{O_2}$) by indirect calorimetry. Reported problems associated with the delivery of a constant F_{IO_2} with mechanical ventilators have been manifested as inaccuracies of $\dot{V}_{O_2}$ measurements with portable metabolic monitors. The use of an external air-oxygen blender has been recommended as a method for providing a stable F_{IO_2} for metabolic measurements (Crit Care Med 1982;10:82). Our study describes and demonstrates a simple alternative method for the delivery of a stable F_{IO_2} during mechanical ventilation. **Methods & Materials:** In the laboratory, we conducted parallel experiments with a 7200a ventilator (Puritan-Bennett Corp, Carlsbad CA) connected to a TTL lung model (Michigan Instruments Inc, Grand Rapids MI). Measurements of oxygen concentration were obtained from the distal outlet of the humidifier using a 1100a mass spectrometer (Perkin-Elmer, Pasadena CA); analog oxygen waveforms were sampled at 200 Hz by a computer-operated data acquisition system (CODAS) (Data Instruments, Akron OH) digitized and stored on a 386-33 microcomputer (AST Research, Irvine CA). In Method I, we used the 7200a with wall air-oxygen gas source, bacterial filter, nondisposable circuit, and Cascade I humidifier with a tower. With Method II, an additional dry Cascade I with a tower was added to the inspiratory limb of the 7200a circuit, distal to the bacterial filter and proximal to the 'wet' Cascade I. In Method III, the 7200a with standard ventilator circuit was

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set up with air-oxygen inlets both connected to an external blender by using a Y connector to high pressure hoses, with the percent-oxygen selector at varying percentages. All methods were tested with the 7200a in CMV; square and ramp wave; V_T 1000 mL; f 10; $\dot{V}$ 40, 60, 80 L/min; and at F_{IO_2} settings of 0.40, 0.60, and 0.80. **Results:** Method I showed the largest overall fluctuation with an F_{IO_2} difference of 0 to 0.005 (0.5%). Method II had an overall fluctuation in inspiratory gas with F_{IO_2} difference of 0 to 0.002 (0.2%). Method III had an overall fluctuation in inspiratory gas with an F_{IO_2} difference of 0 to 0.001 (0.1%). **Experience:** The 0.002 (0.2%) fluctuation in F_{IO_2} stability noted with the additional in-line Cascade would result in an error of measured $\dot{V}_{O_2}$ of 0% to 0.7% in the clinical setting where F_{IO_2}s are typically 0.30-0.60 and $\dot{V}_{O_2}$s are 150-450 mL/min. **Conclusion:** This study suggests that the use of an additional 'dry' Cascade humidifier is a simple and effective alternative to an external blender. Further investigation is needed to test this method and its effectiveness in other ventilator and humidifier systems as a way of controlling F_{IO_2} stability. (OF-91-102)

Ventilatory Drive and Muscle Performance during Recovery from Acute Ventilatory Failure—Cecil Borel MD, Patricia Bates RRT, Jeanne Teitelbaum MD. Johns Hopkins Medical Institutions, *Baltimore, Maryland.*

Acute ventilatory failure (AVF) in myasthenia gravis (MG) and Guillain-Barre (GB) syndrome is the result of ventilatory muscle weakness. We investigated patients with failure to wean (FTW) from mechanical ventilation during acute GB or MG as a model of the role of ventilatory muscle weakness in weaning from mechanical ventilation; 3 patients (2 GB, 1 MG) were enrolled in this study. All FTW occurred on the Puritan-Bennett 7200a ventilator using low IMV and pressure support or total pressure support. We monitored ventilatory mechanics during T-piece trials using the MedGraphics Critical Care Management-Respiratory Pressures Module (CCM-RPM) System and a low-flow (valveless) system. Trial duration was determined by patient complaints of tiredness (failure) or after a predetermined duration set by the investigators (success). Mean (SD) diaphragmatic strength, as measured by P_{dimax}, was initially poor (12 [5] cm H_2O) but improved significantly with recovery (27 [3] cm H_2O), $p < 0.05$. Ventilatory drive, as measured by P_{100}, also increased significantly during failing trials (3.7 to 5.2 cm H_2O/s, $p < 0.001$) but was unchanged in successful trials. End-tidal CO_2 (P_{etCO_2}) increased during failing trials (40 to 43 torr, $p < 0.01$) but was unchanged in successful trials. The ventilatory response to CO_2, as measured by the slope of P_{100}/P_{etCO_2}, revealed an exaggerated mean (SD) response to CO_2 (0.8 [0.1] cm H_2O/torr, normal 0.4-0.8). The mean (SD) slope of minute ventilation response to CO_2 remained depressed (0.6 [0.2] L/min/torr, normal 2-4). Minute ventilation measured at the end of CO_2 rebreathing showed the strongest correlation with recovery ($r = 0.83$, $p < 0.0002$). These results suggest that patients with ventilatory muscle weakness are capable of increasing ventilatory drive but not the minute ventilatory response during AVF. Recovery from FTW may be predicted by P_{dimax} or the CO_2-stimulated minute ventilation. (OF-91-168)

Ventilatory Drive Assessment Using Inhaled CO_2—Sharon Day RRT, Neil R MacIntyre MD, W Ben Vernon MD, Sherry Whitfield RRT. Duke University Medical Center, *Durham, North Carolina.*

Introduction: One criterion used to determine the presence of brain-stem function is assessment of the ventilatory drive response to acute elevations in $P_{CO_2} > 60$ torr. To achieve this increase in P_{CO_2}, ventilatory support is usually interrupted for 6-10 min. Because of this prolonged apneic period, hypoxemia can be a consequence of this maneuver. We reasoned that a gas mixture of 10% CO_2 and 90% O_2 could be used to rapidly raise P_{CO_2} in order to assess ventilatory drive while preserving adequate oxygenation. **Method:** Patients who needed evaluation of brain-stem function were studied, with a capnograph and an oximeter used to monitor the patients and to establish baseline levels. After baseline blood gases were drawn, the patients were manually ventilated with a 10% CO_2-90% O_2 mixture until the capnograph stabilized at an exhaled CO_2 of ≥ 60 torr. Manual ventilation was stopped and the patient and capnograph were observed for signs of ventilatory effort for a maximum of 2 min. The S_{pO_2} was monitored with an oximeter so the procedure could be terminated if S_{pO_2} fell below 85%. Following the observation segment, arterial blood gases were drawn and the patients placed back on mechanical ventilation. **Results:** 14 patients were assessed; mean (SD) data are summarized below.

Pretest P_{etCO_2}	38.5 (7.9) torr
Posttest P_{etCO_2}	67.4 (7.6) torr
S_{pO_2} at end of test	343 (112) torr
Time for entire procedure	2.7 (1.3) min
Number of patients not responding to elevated P_{CO_2}	13

Conclusion: Ventilation with 10% CO_2-90% O_2 is a safe, efficient way to rapidly raise CO_2 levels and maintain S_{pO_2} during assessment of ventilatory drive for evaluation of brain-stem function. The P_{CO_2} can rise above 60 torr in less than 2 min, and adequate levels of oxygenation can be maintained throughout the test. (OF-91-066)

The Physiologic Response to Chest Physical Therapy (CPT) in the Critically Ill—Marcia S Kemper BA CRTT, Charles Weissman MD, Allen I Hyman MD. Columbia University, *New York, New York.*

Introduction: CPT causes sudden alterations in pulmonary and cardiovascular function. We studied how increased O_2 needs are met during CPT in critically ill ventilator-dependent surgical patients (pts). **Methods**: 30 studies were performed on 25 pts with radial (RA) and pulmonary (PA) artery catheters. The Deltatrac metabolic cart was used to determine $\dot{V}_{O_2}$, $\dot{V}_{CO_2}$, and $\dot{V}_E$; the cart was validated and calibrated with precise gas

and interfaced with the ventilator per manufacturer's guidelines. Simultaneous samples were drawn from the PA and RA for ABG and S_{aO_2} analysis and matched with the corresponding metabolic and hemodynamic values for that minute. They were drawn (1) while resting, (2) immediately after CPT, and (3) on return to resting. Extraction ratio (ER) = $(C_{aO_2} - C_{\bar{v}O_2})/C_{aO_2}$. Delivered O_2: $D_{O_2} = \dot{V}_{O_2}/ER$. SVR = systemic vascular resistance; C.O. = cardiac output; SV = stroke volume. SBP = systolic blood pressure, and DBP = diastolic blood pressure. **Results:** Results are mean (SD).

	$\dot{V}O_2$ (mL/min)	P_aO_2 (torr)	$\dot{V}CO_2$ (mL/min)	P_aCO_2 (torr)	$\dot{V}_E$ (L/min)	SVR (dyne · s · cm 5)
1	231 (55)	109 (26)	186 (45)	37 3 (4 5)	9 1 (3.3)	1033 (408)
2	346 (90)*	99 (24)	254 (55)*	39 4 (5 7)*	12 5 (4.6)*	1116 (593)
3	240 (59)	102 (23)	194 (47)	37 6 (4 7)	9.4 (3.1)	955 (278)

	ER (bpm)	HR (L/min)	C O (mL/min)	DO_2 (mL/beat)	SV (torr)	SBP/DBP
1	0 24 (0.05)	97 (16)	7 2 (2 5)	990 (338)	73 (23)	134 (25)/68 (14)
2	0 32 (0 07)*	106 (15)*	8 1 (2 6)*	1122 (375)*	77 (28)	156 (31)/77 (16)*
3	0.24 (0.03)	97 (15)	7 0 (1 4)	975 (219)	71 (10)	127 (25)/64 (12)

*Significance 1 vs 2, $p < 0.05$.

Conclusion: During CPT, increased O_2 needs were accomplished by multiple systems. Increased $\dot{V}_{O_2}$ was met mainly by extraction, with only small increases in delivery. The small increase in C.O. was due mainly to increased HR, not SV. $\dot{V}_E$ increased, preserving P_{aO_2}, but was insufficient to prevent changes in P_{aCO_2}. SVR changed little, implying an exercise-like response. We believe that CPT adds stress to an already stressed system. Others have reported cardiac ischemia in some patients during CPT. Reducing respiratory work during CPT may be possible by mechanically increasing $\dot{V}_E$. (OF-91-075)

Inspiratory Work and Performance Characteristics of 4 Methods of Inspiratory Threshold Loading—Michael S Benson BS RRT, Mikio Abe MD, Leonard D Hudson MD, David J Pierson MD. Harborview Medical Center, *Seattle, Washington.*

Introduction: Inspiratory threshold loading (ITL) is a technique used to strengthen respiratory muscles and evaluate their endurance. Measurements using ITL may be important in predicting weaning success. Current ITL devices employ a mouthpiece and are not designed for intubated/ventilated patients. **Methods & Materials:** We adapted 4 ITL devices for use in a ventilator circuit, and evaluated relative work and performance using a spontaneous breathing model (SBM) (Chest 1989; 96:564-571). Work and performance were measured with a computer-generated graphics program (Leonardo, Hamilton Medical Inc). The SBM was attached to a Hamilton Veolar Ventilator in CPAP mode. Spontaneous ventilation was adjusted to maintain a mean (SD) V_T of 500 (508 [37]) mL, f 15/min, and an I-E ratio of 1:3. Test lung compliance was set at 40 mL/cm H_2O. ITL devices tested were a 10 cm H_2O water column PEEP device (10WD), a 10 cm H_2O weighted-ball PEEP device (10WBD), a 10 cm H_2O spring-loaded PEEP device (10SLD), and a spring-loaded inspiratory muscle trainer (HealthScan Products Inc). The spring-loaded PEEP device and the inspiratory muscle trainer (IMT) were tested at the 20 cm H_2O level. The weighted-ball device and water column would not perform at 20 cm H_2O due to turbulence. Each device was inverted and placed at the inspiratory outlet of the CPAP ventilator. Volume, circuit pressure, lung pressure, and flow were recorded as the ventilator cycled. 3 separate SLD and IMT devices were tested to observe for variation. PIP and MIP were calculated from test-lung pressure tracings. Inspiratory work of breathing was calculated using area measurements of pressure-volume curves (Respiratory Muscle Energetics/Handbook of Physiology, American Physiological Society 1986:481-509). **Results:**

Device	Inspiratory Work kg · m/min (SD)	PIP cm H_2O (SD)	MIP cm H_2O (SD)	V_T mL (SD)
10 WD*	0.971	-20.0	-10.6	456
10 WBD*	-	-21.3	-14 7	515
10 SLD†	0.725 (0.089)	-13.8 (0 7)	- 8.1 (0.5)	480 (8)
20 SLD†	1.735 (0.137)	-28 1 (1.7)	-17.9 (1.3)	501 (25)
10 IMT†	0.858 (0.054)	-13.3 (0 6)	- 8.8 (0.6)	531 (6)
20 IMT†	1.524 (0.038)	-22.1 (0.8)	-14 4 (0.6)	560 (34)

*Single measurement made.
†Three measurements made.

WD functioned well at 10 cm H_2O but would not be practical for ventilator use. WBD did not function well in a circuit due to turbulence. The SLD and the IMT functioned well as ITL devices by providing a consistent level of inspiratory work. The SLD showed some intraproduct variability. At 20 cm H_2O, pressure level markings on the IMT overestimate the mean inspiratory threshhold pressure. **Conclusions:** We conclude that the SLD and the IMT devices are practical to use for ITL in a ventilator circuit. (OF-91-162)

Pentamidine, Ribavirin, and Surfactant Aerosols: Systems and Techniques

Aerosolized Pentamidine: Prophylaxis against *Pneumocystis carinii* Pneumonia (PCP) Is Well Tolerated in Children with AIDS—Theresa A Orcutt AA RRT, Cynthia R Godwin BA RRT, Philip A Pizzo MD, Frederick P Ognibene MD. National Institutes of Health, *Bethesda, Maryland.*

Introduction: The purpose of this study was to determine whether children with AIDS could tolerate aerosolized pentamidine (AP) using the regimen recommended for adults with AIDS, and to determine what adjustments, if any, would be necessary for this patient population. **Methods**: Pediatric patients were eligible for AP if they had either CD-4 counts < 500 cells/mm^3 or a documented sulfa intolerance. Children had heart rate (HR), respiratory rate (Rf), breath sounds (BS), and oxygen saturation (OS) assessed prior to, during, and after therapy. Pentamidine (300 mg in 6 mL of sterile H_2O) was

administered via a Respirgard II nebulizer on a monthly schedule. Aerosolized bronchodilators were given as pretreatment to children who had a history of bronchospasm and to those children who developed bronchspasm during therapy. **Results**: Over a 16-mo period (8/89 to 12/90), 20 patients received a total of 128 treatments (average 6.4 treatments/patient; range 1-12 treatments). Age ranged from 3 to 18 y (mean 10.5 y); 14 of these patients were < 13 y. All patients had CD-4 counts < 500 cells/mm^3 (mean 136.5 cells/mm^3). Treatment duration ranged from 15 to 90 min (mean 31.8 min). OS ranged from 96-100% during and after therapy. AP treatments were tolerated by all patients. During therapy, HR, Rf, and BS did not change significantly. 4 of the 20 patients required bronchodilators as pretreatment to therapy. 15 patients experienced short episodes of coughing, which were relieved by taking sips of liquid; 13 complained of a bitter or bad taste, and 5 had complaints of a burning sensation in the back of the throat. During this limited follow-up (mean time 6.4 mo), none of the 20 patients developed PCP while on AP prophylaxis. **Conclusion**: AP was tolerated well by the pediatric patients in this study. The major side effect was coughing; however, it was relieved with sips of liquid. Bronchospasm, which occurred in 20% of the patients, was reversible with bronchodilators. Although efficacy was not formally studied, no patients developed PCP during the 6.4 mo follow-up. Because AP prophylaxis is tolerated so well, efficacy studies against PCP in children seem warranted. (OF-91-018)

Pentamidine Deposition with a Modified Respirgard Nebulizer—Bob Demers BS RRT, Baystate Medical Center, *Springfield, Massachusetts*; Gerald Smaldone MD PhD, SUNY-Stony Brook, *Stony Brook, New York.*

We use a Marquest Respirgard nebulizer that has been interfaced to a Vital Signs CPAP Mask to administer aerosolized pentamidine in order to scavenge all droplet nuclei or aerosol droplets that might be exhaled or coughed out by patients. Several clinicians have challenged us to verify that drug deposition is not adversely affected by modifying the nebulizer's conventional configuration. A method previously described (Am Rev Respir Dis 1991;143:727-737) was used; radioactive-tagged pentamidine was administered to a test subject using the conventional and the modified Respirgard. Tidal (TV) and minute ventilation (MV) were measured (LS-75, Bourns Medical Systems, Riverside CA), while total and regional drug deposition (correlated with radioactivity) was quantified with a scintillation camera (Dyna Camera®, Picker Corp, Northford CT). During pentamidine administration with the unmodified Respirgard, MV averaged 5.71 L and cumulative radioactivity was 11,193 counts. During drug delivery with the modified nebulizer, MV averaged 8.69 L and cumulative net radioactivity was 21,559 counts. Differential deposition of drug was identical. Thus, pentamidine delivery via the modified apparatus was associated with a moderate (52%) increase in MV and a substantial (93%) increase in drug deposition. In summary, interfacing a Vital Signs CPAP Mask to a Marquest Respirgard was associated with an appreciable enhancement of drug deposition in a single healthy volunteer under the prevailing conditions. (OF-91-167)

Ribavirin Delivery to Non-Ventilated Patients—Evan Steinberg MD, John Cefaratt BS RRT, Kaiser Permanente, *Los Angeles, California.*

Ribavirin administration to pediatric patients < 3 y of age with severe RSV pneumonia has resulted in major concerns in terms of exposure and health risks (eg, teratogenicity). We sought to lower the exposure level to that established as safe by the EPA (≤ 2.7 ug/m^3). With a prototype vacuum system, we conducted a 3-part study of a combination double-chambered hood/tent for administration of ribavirin to non-ventilated patients. Part 1 was control—ribavirin to a hood within an O_2 canopy tent. In Part 2, a high-flow vacuum exhaust system was added. During Part 3, we employed the mist generator of the canopy tent from the second study to saturate the environment of the tent external to the hood so as not to decrease efficacy of the ribavirin. Air samples were taken from 3 points: nearest, midpoint, and fartherest from source, for 5-6 h each. Sample filters were assigned random numbers and sent for analysis. Time-weighted averages indicated a high exposure level for Part 1 (123.0 ug/m^3); Part 2 20.7 ug/m^3 (83.2% reduction); Part 3 < 2.13 ug/m^3—an 89.7% reduction from Part 2, and 98.7% decrease from Part 1. The end result is > 21.1% below the safe standard. We recommend that ribavirin administration to nonventilated patients incorporate a double-chambered hood/O_2 canopy tent, a high-flow vacuum exhaust, and a high-output mist generator. (OF-91-095)

PEFR as an Early Indicator of Filter Occlusion due to Surfactant Aerosol Therapy—Carl F Haas MLS RRT, Linda M Folk RRT, John G Weg MD, University of Michigan Medical Center, *Ann Arbor, Michigan;* David S Zaccardelli PharmD, Burroughs-Wellcome Co, *Research Triangle Park, North Carolina.*

Introduction: Dense aerosols such as artificial surfactant may pose risk for obstruction to ventilators using expiratory filters to protect sensors. **Hypothesis**: PEFR is an earlier indicator of filter occlusion than either baseline pressure (B-P) or PIP when aerosolizing artificial surfactant. **Method**: 4 new Star bacterial filters were studied with continuous nebulization of artificial surfactant (Exosurf®). Predetermined endpoints were defined as (1) PIP of 100 cm H_2O or (2) filter membrane rupture. All 4 filters were studied to an endpoint; 2 were studied during 4 hours of nebulization, autoclaved, and run to endpoint. A Vortran Intermittent Signal Activated Nebulizer was placed in parallel with a Puritan-Bennett (PB) 7200a ventilator. The ventilator and nebulizer were each set to deliver 50% of the V_T and flow, so that the total delivered V_T = 1.0 L, flow = 80 L/min, f = 20, and PEEP = 10 cm H_2O. The lung model was 3 rubber, foam-lined test lungs connected in parallel. A Star bacterial filter was connected in series proximal to the PB expiratory filter. Pressure at the proximal filter inlet (P1) and outlet (P2) were continually recorded. Expiratory flow was mon-

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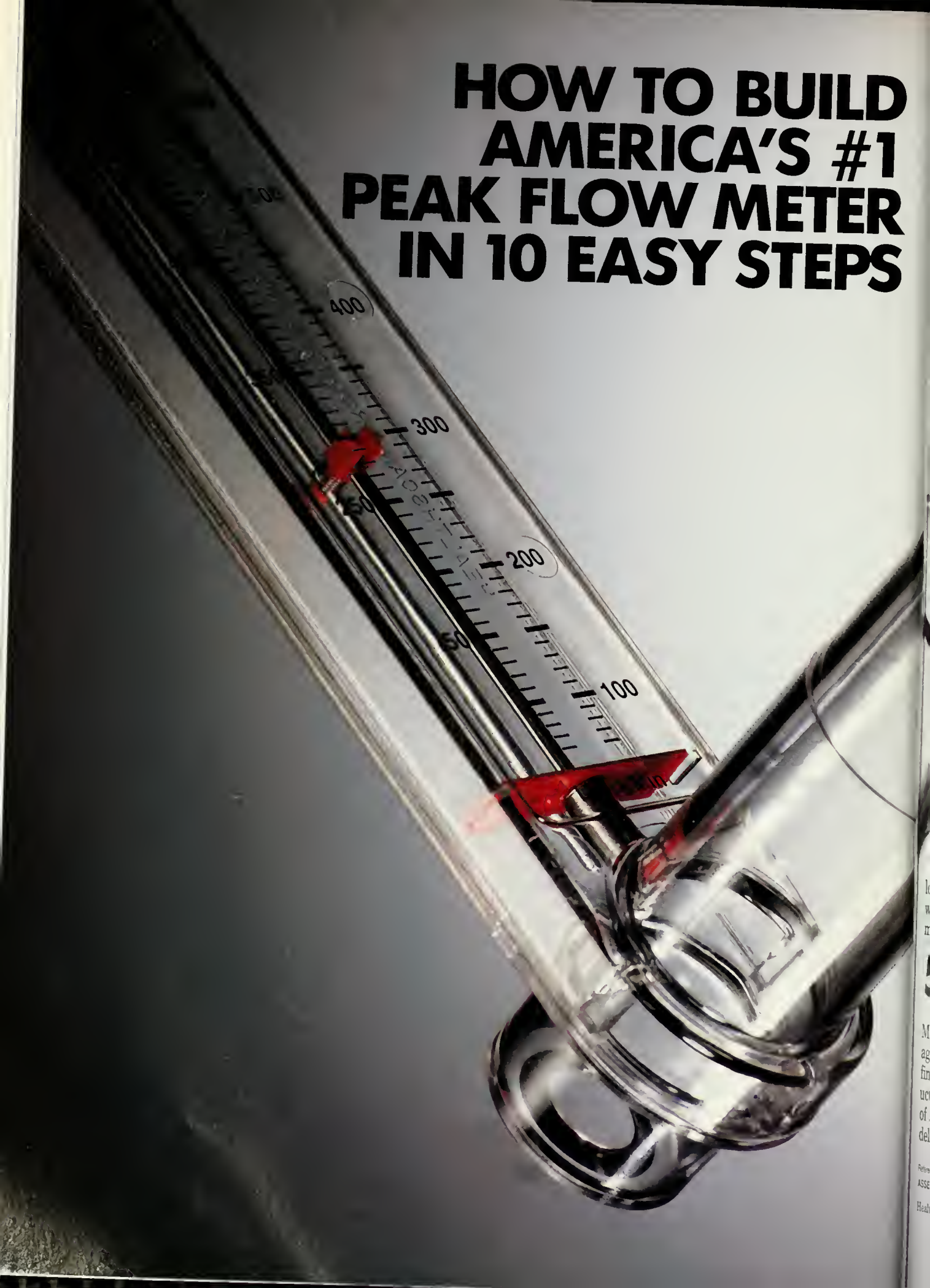

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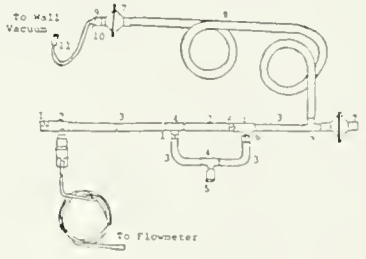
itored with a PB Waveform package. A printout of PEFR was obtained every h until a drop of ≈20% occurred, then every 30 min until an ≈50% drop occurred, and then every 2-10 min to endpoint. PEFR values were measured from the printout. A 20% drop in PEFR, a 20% rise in P1 PIP, or a 25% rise in P1 B-P were considered clinically significant. **Results**: Results are mean (SD). Useful filter duration was 6.84 (1.15) h. Initial PEFR was 143.8 (4.8) L/min and a 20% drop occurred at 6.03 (1.03) h. Initial P1 B-P was 10.5 (0.58) cm H_2O, and a 25% rise occurred at 6.3 (1.1) h. Initial P1 PIP was 74.5 (3.1) cm H_2O, and a 20% increase occurred at 6.8 (1.2) h when PEFR had dropped to ≈50%. Time until clinical significance for PEFR vs P1 B-P ($p < 0.04$) and PEFR vs P1 PIP ($p < 0.004$) was statistically significant. Once pressures began to rise, they approached 100 cm H_2O within 5-20 min. P2 PIP paralleled P1 PIP. P2 B-P, which reflects the baseline pressure the ventilator would monitor, did not rise in any trial. PEFR waveform had a sharp peak and steep slope initially. As PEFR decreased, the peak blunted and the return to baseline took longer (flatter slope). When PEFR dropped by 45-50%, the peak was very blunted and considerable "auto-PEEP" occurred. **Conclusion**: Using this model, PEFR was an earlier indicator of ventilator filter obstruction. A significant drop in PEFR occurred 15-30 min before pressure increased. Pressure increased only after filter resistance increased enough to lengthen expiratory time and cause air trapping. (Supported in part by the Burroughs-Wellcome Co.) (OF-91-088)

An Alternative Method of Reducing Environmental Aerosolized Pentamidine—Charles Kettell RRT, Kathryn Harris RRT, Maine Medical Center, *Portland, Maine.*

Introduction: We proposed a method of delivering aerosolized pentamidine that prevents the drug from being released into the environment and avoids the need for a costly tent or booth evacuation system. **Method:** The system consists of a circuit constructed with two Marquest Respirgard II Nebulizer Systems, other readily available parts, and wall vacuum (see figure). The standard method of delivering pentamidine using



(1) Opaque Marquest one-way valve, (2) Marquest Respirgard II nebulizer w/blue 'T' & O_2 tubing, (3) 1 link (approximately 6") disposable corrugated tubing, (4) Briggs T-adapter, (5) mouthpiece, (6) Blue Marquest one-way valve, (7) Marquest bacteria filter, (8) 72" disposable corrugated tubing, (9) Marquest 22-mm adapter (from Respirgard II system), (10) Bird 15-mm-OD x 1/4" tubing adapter, and (11) 12" suction tubing connected to wall vacuum @ 120 torr with no extension tubing. Note: Circuit should be set up exactly as described, modification could result in malfunction.

one nebulizer system allows pentamidine to vent to the environment when the patient removes the mouthpiece, thus the need for a booth. With our setup, when the patient takes the mouthpiece out of his mouth, the vacuum system diverts the medication so that none is released to the environment. **Results:** We have checked the environment around the mouthpiece using oxygen as a marker, have found no leaks, and have verified that the one-way valves in the system seat properly. **Experience:** This system is still in the early phase of development and has not been used on patients. **Conclusions:** Pentamidine remains part of the standard chemotherapy for *Pneumocystis carinii*. The standard system to decrease environmental pentamidine exposure (to reduce potential effects on unborn children and caregivers' lungs) is an isolation booth. We offer an alternative that provides environmental protection from pentamidine without creating an additional source of stigma or intensifying patient anxiety. During pentamidine delivery, the caregiver wears a mask as a barrier (against potentially undiagnoised tuberculosis) as would be appropriate if treating such a patient with aerosolized drug other than pentamidine. Further evaluation is necessary to see whether this method provides an equivalent drug dose and whether it is practical for widespread use. (OF-91-142)

Inexpensive High Flow Evacuation of a Ribavirin Administration System—Charles Kettell RRT, Kathryn Harris RRT, Maine Medical Center, *Portland, Maine.*

Introduction: We created a scavenging system from existing equipment to decrease the environmental levels of ribavirin during administration. **Method:** In a manner similar to that described by others, we created a double enclosure on a crib, supplied ribavirin and an additional continuous blended-gas supply for the patient to breathe in an inner enclosure, and used the outer enclosure (adult oxygen tent) to contain the ribavirin. We used an Emerson Pleural Suction Pump (Model PS 72) connected (with modifications) to 2 separate Intertech bacteria filters to continuously evacuate the adult tent through 2 58-in-long 22-mm-ID smooth-bore tubes on either side of the inner enclosure. We replaced filters when the vacuum level had risen 5 cm H_2O beyond the initial level. The tent inlets were used to secure the various tubings while improving the patency of the enclosure. We also cut a 4-in square 'inlet' hole in the top foot of the tent to allow fresh air into the tent. **Experience:** In both a mock trial and three treated patients, we monitored ribavirin levels outside the adult tent, at the suction pump exhaust, inside the adult tent, and at breathing zones of participating caregivers. We detected ribavirin levels only inside the tent during administration and within 5 min of cessation of ribavirin, with the highest outside speculative exposure < 0.8 $\mu g/m^3$, well below the permissible exposure level of 2.7 $\mu g/m^3$ for an 8-h time-weighted average and all personal exposures below the exposure level. No leaks of ribavirin were detected from the double-hood system. **Conclusion:** We believe the Emerson Pleural Suction Pump, with its flow just prior to filter change of 240 L/min, and the 4-in square inlet in the adult tent, which allows fresh gas in to flush out the drug,

are both useful improvements to previously described systems. (OF-91-143)

Evaluation of Procedures for Protecting Employees from Exposure to Aerosolized Ribavirin—Debra Fox BHS RRT, Thomas Bloxham MD, HCA Wesley Medical Center, *Wichita, Kansas*; Steven W Lenhart, John A Decker, National Institute for Occupational Safety and Health, *Cincinnati, Ohio.*

Introduction: While no occupational exposure criteria exist for ribavirin, the drug has been found to be teratogenic and/or embryolethal in some animal species in which it has been tested. Therefore, exposures to ribavirin by individuals other than those receiving medical treatment should be avoided. **Methods:** At our hospital, ribavirin is administered via "Care Cube" oxyhood. A 24% venturi mask adapter operated at 2 L/min, 6-in corrugated tubing, and bacterial filter are placed in the hood's outlet to scavenge escaping aerosol. A 2-phase study was conducted to evaluate this administration method and ability of air-purifying respirators to control exposure of respiratory therapists and nurses to aerosolized ribavirin. Lapel, in-mask, and in-hood samples were collected during Phase I while ribavirin was administered to infant mannequins to simulate patients. Each worker wore a 3M 9920 disposable respirator; quantitative fit testing was not conducted. Lapel, in-mask, and in-hood samples were collected during Phase II while ribavirin was administered to a patient. Workers wore either a 3M 9970 high-efficiency disposable respirator or an MSA half-mask respirator with high-efficiency cartridges. Respirator type and face-piece size were determined from quantitative fit tests. All ribavirin samples were collected and analyzed according to NIOSH Method 5027. **Results:** For Phase I, 8-h time-weighted average (TWA) lapel concentrations ranged from 87 to 323 $\mu g/m^3$ (n = 6); sampling durations ranged from 173 to 371 min. 10/17 in-mask samples contained no detectable ribavirin. Estimated 8-h TWA in-mask concentrations ranged from 3 to 21 $\mu g/m^3$. Short-term in-hood concentrations ranged from 1.3 to 123 mg/m^3 (n = 21). For Phase II, 8-h TWA lapel concentrations ranged from 40 to 120 $\mu g/m^3$ (n = 7); sampling durations ranged from 45 to 102 min. 7/8 in-mask samples contained no detectable ribavirin; 1 sample was reported at the limit of detection. Estimated 8-h TWA in-mask concentrations ranged from 0.6 to 1.1 $\mu g/m^3$. Short-term in-hood concentrations ranged from 52.7 to 180 mg/m^3 (n = 16). (Short-term in-hood samples collected without the scavenging system ranged from 0.3 to 180 mg/m^3, n = 32.) **Conclusion:** Exposure to aerosolized ribavirin occurred in spite of use of scavenger system. Respirators that are assigned based upon the results of quantitative fit tests may provide adequate protection against aerosolized ribavirin. In-hood concentrations of ribavirin may be less than the expected value of 190 mg/m^3. (OF-91-114)

Evaluation of the Iso-Hood System—A Portable Aerosol Evacuation System—Wanda H Perry MEd RRT, Lloyd E Hayes MD, Walter F Norris RCP RRT, Greenville Memorial Medical Center, *Greenville, South Carolina.*

The Iso-Hood system is a newly developed hood device that serves as a portable evacuation system (MicronAire Corp, Anderson SC). It was developed for use in both in- and outpatient areas of respiratory care and may be indicated for use with procedures such as pentamidine and ribavirin therapy, sputum induction, and high-risk bronchoscopy. The purpose of this study was to evaluate the effectiveness of this system for evacuating and filtering particulate aerosol **Method**: 14 patients in the outpatient pentamidine program participated in the study (13 men, 1 woman, median age 37.5 y). Each patient was positioned under the Iso-Hood system and instructed to cough onto a blood agar plate (held 12 inches from mouth), while a blood agar plate was held simultaneously at the same distance from the Iso-Hood exhaust system. Plates were cultured and colony growths counted. A questionnaire was administered to each patient following therapy. **Results**: A significant difference was found between the number of colonies on the cough plates (median 26) and corresponding exhaust plates (median 0) ($p < 0.0005$ from Wilcoxon signed-rank test). A particle count was also done for 1 patient undergoing pentamidine therapy, which yielded the following results:

Particle Size	Under Iso-Hood	At Exhaust
1 micron	95,772	39,287
3 microns	121,562	30,910
5 microns	95,117	31,005

Patient reaction to the Iso-Hood was extremely favorable. Results from the patient questionnaire were as follows: 92% were not hot inside hood, 71% felt that hood did not restrict movement, 98% felt the technician was accessible and could be easily heard, and 88% felt the Iso-Hood protected their dignity. The experience of the investigators has been that the Iso-Hood is convenient for both technician (portable and easy to clean) and patient. **Conclusion**: This system appears to be effective in filtering and evacuating aerosol particles generated from pentamidine treatment as well as aerosols generated from the sneeze or cough of a patient. Findings suggest that the Iso-Hood system could be used while delivering aerosolized medications as well as to create a cleaner environment for both the health-care worker and patient. (OF-91-061)

Resource Utilization and Cost-Effectiveness

Metabolic Measurements (MM) Influence Physician (MDs) Practice—James M Darin RRT, Charles G Durbin Jr MD, University of Virginia Health Sciences Center, *Charlottesville, Virginia.*

After introducing a respiratory-care-based MM service (limited to intubated patients on $F_{IO_2} \leq 0.6$), we sought to determine whether MDs were using the information to alter patient nutrition plans. Prior to this time, MDs used a stress-modified Harris-Benedict calculation to prescribe nutrition. **Hypothesis**: MDs would learn to use MM to optimize nutrition management. **Method**: MM were performed as ordered. At least one follow-up MM was done within 5-7 days of the initial study.

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MM were performed using a MedGraphics metabolic cart, Model CCM. Resting energy expenditure (REE) was determined by breath-by-breath exhaled-volume measurement and gas analysis. Caloric intake (CAL) for the previous 24 hours and REE were compared. Nutrition management was considered appropriate if the follow-up measurement indicated that the MD had made an appropriate caloric adjustment based on the results of the initial measurement, and was defined as REE and CAL within 30%. **Results**: 79 paired measurements were analyzed. The number of measurements/mo resulting in appropriate management (# Appr) are shown below:

	Aug 90	Sep 90	Oct 90	Nov 90	Dec 90	Jan 91	Feb 91
# Appr	3	6	2	13	10	17	6
Total	6	11	3	16	14	21	8
% Appr	50	55	67	81	71	81	75

MDs' use of MM for CAL alteration increased progressively over this time period. Overall, MDs made appropriate CAL adjustments in 71% of the cases; 90% of these resulted in improved patient matching between REE and CAL. MDs did not make recommended CAL adjustments in 29% of cases; 63% of these resulted in increased difference between REE and CAL. **Conclusions:** Physicians are using the results of MM to alter nutritional support. Use of REE has improved matching of patient diet and caloric use. (OF-91-005)

A Strategy To Reduce Costs Associated with Pulse Oximetry in Non-Critical Care Areas—Michael J Mahlmeister MS RCP RRT, James B Fink MS RCP RRT, Neal H Cohen MD. UCSF Medical Center, *San Francisco, California.*

Introduction: The use of pulse oximeters for monitoring O_2 delivery and adequacy of oxygenation in noncritical care environments has increased. Between 1987 and 1989, our institution experienced a 375% increase in orders for pulse oximetry in non-critical care areas. In the absence of specific guidelines for S_{pO_2} monitoring, continuous oximetry was provided upon physician request, leading to a 400% increase in oximeter rentals with associated costs of supplies and staff time. We developed a cost-effective program to more efficiently match human resources and equipment availability with patient need. **Method:** In December 1988, guidelines for the use of continuous vs spot-check S_{pO_2} monitoring were developed by an interdisciplinary task force and distributed to all medical staff. During a 2-mo pilot project, 2 nursing units with documented high utilization of S_{pO_2} monitoring each received 2 N-10 pulse oximeters (Nellcor Inc, Hayward CA). The nursing staff performed all S_{pO_2} spot checks, either physician-ordered or nurse-initiated, while continuous S_{pO_2} monitoring remained available through our Respiratory Care Service (RCS). Data were recorded by the nursing personnel each time a spot check was performed. **Results:** 833 spot checks were documented during the 60-d pilot period. 98% (818/833) of spot checks were indicated to be of value by nursing staff, with 30% of the checks resulting in a change in therapy. 37% of the spot checks were nurse-initiated. 155 patients had an S_{pO_2} reading less than 90%, with 77 of those measured for patients breathing room air. All 77 had O_2 therapy initiated or received other therapy as a result of the low S_{pO_2}. Reasons for obtaining spot checks included (1) routine checks 51%, (2) single measurement 31%, (3) assessment of change in O_2 therapy 13%, and (4) assessment of change in clinical status 5%. Utilization of continuous pulse oximetry on these 2 units dropped to 1/5 of pre-pilot levels. **Discussion**: Evaluation of the data by the task force coupled with nursing staff support for the pilot project resulted in the acquisition of N-10 oximeters for all non-critical care nursing units, with appropriate in-service training. At 6-mo follow-up, orders for continuous oximetry had been reduced from an average of 520 d/mo to < 100 d/mo. This program generated a net savings in rentals and supplies of $141,310 over the first 12 mo (after purchasing the N-10s) and allowed RCS to reallocate 1.2 full-time equivalent to critical care staffing. We were unable to identify any untoward consequences or adverse patient outcomes as a result of the change in procedure. **Conclusions**: Use of an interdisciplinary task force involving nursing, respiratory care, and medical staff facilitated the development of a strategy that allowed for convenient, cost-effective, clinically acceptable availability of S_{pO_2} spot-check monitoring. The availability of pulse oximetry monitoring by nursing personnel provided timely, acceptable feedback regarding the clinical status of the patient. We recommend that other institutions explore similar approaches to providing S_{pO_2} monitoring in non-critical care environments. (OF-91-042)

Results of Implementing a Program to Review the Utilization of Pulse Oximetry—Richard M Ford BS RCP RRT, David M Burns MD. UC-San Diego Medical Center, *San Diego, California.*

Pulse oximetry has gained widespread acceptance in the medical community as a standard of care in the surveillance of patients receiving oxygen or mechanical ventilation. The service of pulse oximetry at UCSD Medical Center represents considerable costs that include $250,000 of capital equipment, prior-year rental cost of $21,600, prior-year disposable probe cost of $50,000, and prior-year labor expenses estimated to exceed $25,000. Last year 2,997 oximeter 'new starts' were initiated and 304,180 hours of continuous monitoring provided. The annual increase in oximetry service has exceeded 30% in each of the past 5 years. Upon review, we recognized the potential for significant cost reductions directly related to the timely identification and discontinuance of oximeter monitoring that is not medically necessary. **Methods:** Guidelines for oximetry use were developed and an RCP designated to assess utilization as per approved criteria. Indications for continued oximetry were (1) conditions in which episodes of desaturation are likely or have been observed in the past 24 hours, (2) any patient in whom the F_{IO_2} is > 40%, (3) any patient on mechanical ventilation in the ICUs, and (4) titration of the F_{IO_2} at intervals of < every 4 hours when arterial blood gases are not being performed. The primary criteria for discontinuance was an O_2 saturation > 95% over a 24-h period, without other indications for oximetry monitoring. If the RCP

evaluation showed no medical indication to continue oximetry, the ordering physician was contacted to discontinue the service. **Results:** In the first 2 months of the program, 82/215 (38.1%) of oximetry patients reviewed met criteria for discontinuance; of this group, 36.1% were discontinued within the first 24 hours. Follow-up revealed 112 or 52% of all patients reviewed were actually discontinued within a 72-h period of the initial evaluation. Comparisons for the 12 months preceding the review program indicated (1) oximetry hours reduced by 16.9%, (2) oximetry starts reduced 5%, (3) oximetry hours/patient reduced 12.2%, and (4) oximetry hours in relation to hours of mechanical ventilation and oxygen service reduced 12.6%. **Conclusion:** The Oximetry Review Program at UCSD has facilitated ongoing review of the quality and medical necessity of oximetry, documentation of the indications and effectiveness of care, timely intervention, discontinuance, and development of a database of information to assess usage trends and resource consumption in terms of location, prescriber, and type of patient. Preliminary comparisons demonstrate a protocol implemented by RT can shorten the duration of oximetry use, thus reducing resources and cost associated with providing oximetry service. (OF-91-104)

A 24-Hour Study of O_2 Saturations in 18 Non-Ventilated Patients—Michael S Friel RRT, Susan M Lohse RRT, University Medical Center; Stuart F Quan MD, University of Arizona Health Sciences Center; Linda Kossiver RRT, Pima Medical Institute—*Tucson, Arizona.*

Introduction: The postoperative period following abdominal surgery (POAS) is associated with a decrease in FRC and episodes of hypoxemia. **Purpose:** We wished to determine whether continuous pulse oximetry (PO) is necessary to monitor for hypoxic episodes or whether empiric O_2 alone would minimize hypoxemia and make PO unnecessary. **Hypothesis:** We postulated that POAS patients receiving low-flow O_2 would have fewer long (> 2 min) and short (< 2 min) desats (90%) and that PO would have no measurable impact on patient care. **Methods & Materials:** 18 patients (11 men) mean age 54 y (range 28-72 y) were studied. O_2 sats and pulse rate were recorded using Nellcor N-100 interfaced to Apple II using Profox oximetry program or an Ohmeda 3700 combined with Ohmeda dual strip-chart recorder. 3 patients in the O_2 and air group had a history of tobacco use. Study began on patient's arrival in room and continued for 24 h (mean 20.4 h). **Results:** Measurements were analyzed by non-parametric ANOVA. O_2 (n = 9) and room air (RA, n = 9) groups had higher mean sats ($p < 0.025$) than switchover group (n = 3) (mean sats 95.9, 94.9, 92.3, respectively). Switchover groups were created when caregivers obtained O_2 orders based on observed desats. O_2 and switchovers had fewer short desats ($p < 0.0001$ than RA group. No difference (p = ns) in number of long sats between RA and switchover groups. Significantly fewer ($p < 0.042$) long desats in the O_2 group. **Conclusion:** O_2 group had fewer desats than RA group (3/409). 24 h of PO generally costs more than providing O_2 for same period. A reduction in cost of care may be realized if O_2 not PO is instituted for the 24-h period following AS. (OF-91-161)

Reusing Tracheostomy Tubes in Ventilator-Dependent Children—Angela M Jerome MS RN, Kathryn K McDonald RN BSN, Ellie Zuck Tucker AS RRT, Benita Rogers CRTT, Gerald L Strope MD, Children's Hospital of The King's Daughters, *Norfolk, Virginia.*

Introduction: The cost of weekly tracheostomy (trach) tube changes in our chronically-hospitalized ventilator-dependent children was significant. A procedure for reusing patient-specific uncuffed trach tubes for 6 months (similar to home care) was developed. **Method:** We initiated a procedure that involved reusing our inpatient uncuffed trach tubes. After removal, the trach tube was soaked in hydrogen peroxide and cleaned by one of three specific persons using non-sterile supplies, non-lanolin based soap, and tap water. A quality-control inspection was performed and documented to assure there were no trach-tube deformities. Trach-tube surface cultures were obtained every 2 months. The incidence of bronchitis and tracheitis prior to and after the change in procedure was compared. **Results:** A 2-tailed *t* test showed no significant difference in the incidence of bronchitis or tracheitis for the year prior to and after the change in procedure. This is despite a significantly higher number of patient days on the unit ($p < 0.05$) following the change. Trach-tube surface cultures were negative except for one during early phases of the procedure. The yearly cost prior to reusing trach tubes was $29,203, and the yearly cost after the change was $2,246. **Conclusions:** Reusing uncuffed trach tubes did not increase the incidence of bronchitis or tracheitis in our unit. This procedure provided a safe, cost-effective alternative to using sterile trach tubes for changes on our chronic ventilator-dependent children. (OF-91-117)

The Effect of Respiratory Care Department Management of a Blood Gas Analyzer on Appropriateness of ABG Utilization—Charles G Durbin Jr MD, Kathryn Beasley RRT, James Darin RRT, University of Virginia Health Sciences Center, *Charlottesville, Virginia.*

In Spring 1989, the Surgical ICU (SICU) was moved to a new building. Prior to the move, ABG analysis had been provided by a local STAT Lab, staffed 24 h/d by the clinical laboratory. The move resulted in transporting samples 4 floors to the centralized STAT Lab Bench. Transportation delay resulted in unacceptably slow turnaround (average 37 min) on critically ill patients. After 6 mo an automated blood gas analyzer (Corning 282 ABL) was placed just outside the SICU. RCPs trained in its use were the only personnel permitted to process ABG samples. Quality control and machine maintenance were provided by the clinical laboratory. **Hypothesis**: Because the single SICU-based RCP had to leave the SICU to process the ABG, use of ABGs would decrease and appropriateness of sampling would increase. Previously described algorithm flowchart of appropriate indications for ABG Analysis (Respir Care 1989; 34:269-280) was used to determine the appropriateness of

ABG analysis. All staff (nurse, RCP, physician) could draw or request an ABG, but RCP service for analysis was provided only if the RCP agreed analysis "was appropriate" (other samples were sent to the main laboratory). 448 randomly selected ABGs (148 prior to and 150/mo and 150/y after initiation of RCP service) were retrospectively evaluated. Differences between the number of "appropriate" and "not appropriate" ABGs during each follow-up period (compared to control) in each caregiver group was evaluated with chi-square. **Results:**

	Control	1 Month	p	1 Year	p
RN	42%	73%	.035	73%	0.066
RCP	90%	87%	.813	91%	0.400
ABG/Pt/D	3.8	3.1	3.7		

Conclusions: RCP-managed ABG analysis produced an immediate and sustained improvement in appropriateness of ABG analysis initiated by nurses. No change occurred in the "appropriate" percentage of therapist-initiated ABGs or the number of ABGs/patient/d. The forced educational and collaborative interaction between RCPs and nurses improved nursing decision-making regarding ABG analysis. (OF-91-043)

Five-Day Changes for Heated-Wire Circuits—John Grenon RCP, Lauren Armstrong BA RRT. Children's Hospital of San Francisco, *San Francisco, California.*

The standard of practice in our respiratory department is to change heated wire circuits at Day 5. As a quality assurance issue and because there was little published research on the subject, we attempted to determine the appropriateness of our practice. This study was designed to determine whether there was growth and/or increased growth over time before circuit change at Day 5. **Method**: A total population of 45 patients from NICU, PICU, and adult ICU who were mechanically ventilated for 5 days or more were studied. Isothermal heated-wire circuits with Fisher-Paykel heaters were used. After 48, 72, 96, & 120 hours of ventilation, cultures were taken from 3 sites: the MR600 humidification chamber, the Y-adapter, and the exhalation end of the circuit. Culture swabs were sent to the laboratory, spread onto blood-agar plates, and analyzed for growth and colony counts. **Results**: 50 circuits used for 96 to 120 hours were analyzed. 4 species of gram-negative rods, 3 species of gram-positive cocci, and 1 species of gram-positive rod were identified. No growth was found at the humidifier. 15/50 Y-adapters were positive for growth: 11/15 cultures matched for growth found in patient sputum results prior to the study. 10/50 exhalation sites were positive for growth; 9/10 matched growth found in the patient's sputum prior to the study. There was no increase in colony counts from Day 2 thru Day 5 from any of the cultured sites. **Conclusion**: We conclude that much of the growth that was seen within the circuits was due to contamination from patients' sputum. Our study helped to determine whether we would continue 5-day circuit changes. Further research is needed with a control group in order to validate or disprove our findings. Until then our practice of 5-day circuit changes will continue. (OF-91-001)

Extended Use of Heated Neonatal/Pediatric Ventilator Circuits (HNVC)—Robert M Kacmarek PhD RRT, Patricia English MS RRT, Nancy Vallende BS MT (ASCP) CIC, Cyrus C Hopkins MD. Massachusetts General Hospital, *Boston, Massachusetts.*

Heated neonatal/pediatric ventilator circuits reduce the likelihood of ventilator circuit contamination and have been used beyond the normal 48-h limit without the occurrence of nosocomial infection (Respir Care 1990;35:1089). As a result, we questioned whether these systems could be safely used for extended periods of time. **Methods:** Upon institution of mechanical ventilation (MV), a sputum culture was obtained and MV was provided via a heated Isothermal custom pediatric breathing circuit (Baxter) and Conchatherm plus humidifier (RCI). When the 1.5 L-H_2O feed was empty it was replaced, but the circuit was left intact. A second sputum culture was obtained, as well as swab cultures of the internal orifice of the infant's manual ventilator and endotracheal tube attachment. When the second 1.5 L-H_2O feed was empty, the circuit was removed and a broth washing performed on 18 inches of the inspiratory circuit (IC) closest to the patient. A third sputum culture was performed at this time, as well as cultures of the manual ventilator and the cap used to alternately cover the manual ventilator and circuit Y. **Results:** Data were obtained on 20 patients, with a total of 29 circuits used (5 patients required multiple circuits over a period of wks). Length of circuit use varied from 4 to 10 d (mean [SD] 6.14 [1.6] d). Only 2 IC, 4 MV, and 2 caps showed positive cultures; all demonstrated organisms identified in the sputum at onset of MV. No nosocomial pneumonias developed. **Conclusion:** HNVCs may be safely used for the length of time required to consume 2 1.5-L feeds, provided care is exercised to minimize contamination of the ventilator system. (OF-91-091)

Resuscitation Techniques, Equipment, and Adjuncts

Evaluation of the Effect of Fatigue on Volumes Delivered during Adult Bag-Valve Ventilation (BVV)—Dean Hess MEd RRT, Mark Simmons MS RPFT RRT, Scott Blaukovitch, Tom Doyle, Deb Lightner. York Hospital, *York, Pennsylvania.*

Study Question: What is the effect of fatigue on volumes delivered during BVV? **Methods**: BVV was delivered through a 7-mm-ID endotracheal tube fitted to a Michigan Instruments TTL with a compliance of 50 mL/cm H_2O. An adult Laerdal bag-valve resuscitator with gas collection head was used. A Bear VM-90 was used to measure exhaled volumes; its accuracy was confirmed using a calibration syringe. All participants (n = 28) were BCLS certified and were familiar with BVV technique. Each person was instructed to ventilate the TTL for 10 min at a rate of 12/min with the same technique used for patient ventilation. $\dot{V}_E$ and f were measured for Min-

used for patient ventilation. $\dot{V}_E$ and f were measured for Minutes 2, 5, and 9. V_T was calculated by dividing $\dot{V}_E$ by f. Grip-strength was measured using a mechanical digital grip-strength tester for both the dependent and independent hands before and immediately following each 10-min ventilation trial. Ventilation was delivered using 1 hand and 2 hands, with the order randomly determined and a 15-min recovery period between the 2 test periods. Summary data were determined as mean (SD). Differences between volumes during the 3 measurement periods for 1- and 2-handed ventilation were evaluated by 2-way repeated measures ANOVA. Differences in grip-strength were evaluated using a paired *t* test. **Results**: Using 1 hand to squeeze the bag, the volumes delivered were 0.72 (0.17) L, 0.72 (0.17) L, and 0.73 (0.14) L for Minutes 2, 5, and 9, respectively. Using 2 hands to squeeze the bag, the volumes delivered were 0.96 (0.20) L, 0.94 (0.20) L, and 0.93 (0.19) L for Minutes 2, 5, and 9, respectively. There was no significant change in volumes delivered for the 3 measurement periods ($p = 0.84$), but the volumes delivered using 2 hands were significantly greater than those delivered using 1 hand ($p < 0.001$). For volume delivered, there was no significant interaction between time of measurement and using 1 hand or 2 hands to squeeze the bag ($p = 0.27$). When 1 hand was used, there was a small but significant decrease in the grip-strength of the hand used to squeeze the bag (35 [9] kg before, 33 [9] kg after, $p = 0.007$), but no change in grip-strength of the other hand (31 [9] kg before, 31 [9] kg after, $p = 0.47$). When 2 hands were used to squeeze the bag, there was no significant change in grip-strength for the dependent hand (34 [9] kg before, 34 [9] kg after, $p = 0.79$) or the independent hand (31 [9] kg before, 31 [8] kg after, $p = 0.57$). **Conclusions**: For this short-term study (10 min), fatigue as measured by digital grip-strength changed very little and had no significant effect on volumes delivered. For volume delivered, the effect of using 2 hands to squeeze the bag was greater than the effect of fatigue. Further work is needed to assess the effect of fatigue when using a bag-valve resuscitator for longer periods of time, when using different types of bag-valve resuscitators, with different lung compliances and with different airway resistances. (OF-91-029)

Resistance to Flow through Adult Bag-Valve Resuscitators—Dean Hess MEd RRT, Mark Simmons MS RPFT RRT, Matthew Vaughn. York Hospital, *York, Pennsylvania.*

Study Question: What is inspiratory and expiratory flow resistance of adult resuscitators? **Methods**: We evaluated 12 adult resuscitators (Ambu, Code Blue, DMR, Hope 4, Hospitak, Hudson, Intertech, Laerdal, Mercury, Respironics, SPUR, Vitalograph). Expiratory resistance was evaluated by directing flow of O_2 through the valve in direction that flow moves when patient exhales. Inspiratory resistance was evaluated by directing O_2 through the valve in direction that flow moves when bag is squeezed. Flow was controlled by Timeter 0-75 flowmeter and measured using a calibrated Timeter RT-200. Flows of 10, 20, 30, 40, 50, 60, 70, 80, and 90 L/min were used. Back pressure due to the resistance of the resuscitator valves was measured using a calibrated Timeter RT-200. Resistance was calculated by dividing back pressure by flow; 5 measurements were made at each flow setting for each resuscitator. **Statistical Analysis:** Analysis of variance and calculations of mean (SD). **Results**: Differences exist in resistances between flows ($p < 0.001$), between inspiratory and expiratory flows ($p < 0.001$), and between resuscitators ($p < 0.001$ in each case). Significant interaction effects were seen for valve resistance between resuscitator brands, flows, and inspiratory/expiratory flows ($p < 0.001$).

Resuscitators	Inspiratory Resistance (mean [SD] in cm H_2O/L/s at 90 L/min flow)	Expiratory Resistance
Ambu	3.3 (0.01)	3.6 (0.01)
Code Blue	4.5 (0.02)	2.5 (0.02)
DMR	7.7 (0.12)	3.3 (0.01)
Hope 4	3.6 (0.01)	2.0 (0.04)
Hospitak	10.4 (0.01)	10.4 (0.11)
Hudson	4.0 (0.02)	2.6 (0.03)
Intertech	5.3 (0.03)	3.6 (0.01)
Laerdal	4.2 (0.02)	2.9 (0.05)
Mercury	7.4 (0.02)	4.6 (0.02)
Respironics	4.1 (0.01)	2.3 (0.01)
SPUR	2.5 (0.04)	3.9 (0.04)
Vitalograph	13.7 (0.1)	7.2 (1.11)

Resuscitators	Inspiratory Resistance (mean [SD] in cm H_2O/L/s at 10 L/min flow)	Expiratory Resistance
Ambu	5.3 (0.04)	4.3 (0.17)
Code Blue	4.9 (0.18)	2.0 (0.31)
DMR	4.3 (0.03)	0.5 (0.01)
Hope 4	4.6 (0.01)	8.8 (0.18)
Hospitak	16.1 (0.03)	11.2 (0.08)
Hudson	5.8 (0.25)	2.2 (0.12)
Intertech	7.1 (0.24)	2.9 (0.05)
Laerdal	4.7 (0.28)	3.8 (0.25)
Mercury	9.3 (0.07)	2.6 (0.03)
Respironics	7.1 (0.09)	8.0 (0.2)
SPUR	1.6 (0.24)	0.6 (0.03)
Vitalograph	11.4 (0.2)	6.4 (1.45)

Conclusions: Differences in resistance to flow were significant—in some cases perhaps excessive. Excessive expiratory resistance may prolong exhalation, resulting in auto-PEEP. Excessive inspiratory resistance may produce fatigue in hand of person squeezing bag. Further work is needed to determine the clinical importance of these findings. (OF-91-030)

The Effect of Inlet Pressure on the Flow from O_2-Powered Resuscitators—Dean Hess MEd RRT, Mark Simmons MS RPFT RRT, Tony Ruppert CRTT, Sandra McClure CRTT. York Hospital, *York, Pennsylvania.*

Although seldom used in the hospital, O_2-powered resuscitators are commonly used during field resuscitation. Due to

concerns regarding gastric insufflation and barotrauma, American Heart Association (AHA) standards state that the flow from these devices should be 40 L/min (JAMA 1986;255: 2934). **Study Question**: What is the effect of changes in lung compliance and inlet pressure on the flow delivered from an O_2-powered resuscitator? **Methods**: A Life Support Products and an O-Two Systems O_2-powered resuscitator were evaluated. An adjustable regulator was used to alter the inlet O_2 pressure to the resuscitator. Inlet pressures of 30, 35, 40, 45, 50, 55, and 60 psi were used and confirmed with a calibrated Timeter RT-200. Flow was directed from the O_2-powered resuscitator into a Michigan Instruments TTL for 1.5 s and measured by an in-line calibrated Timeter RT-200. Compliance settings of 0.015, 0.02, 0.05, and 0.1 L/cm H_2O were used; 5 measurements were made for each combination of pressure and compliance settings for each resuscitator. Statistical analysis consisted of ANOVA and calculation of mean (SD). **Results**: The mean (SD) flows (L/min) measured were 26.9 (1.3), 30.1 (1.9), 32.7 (1.9), 36.9 (0.8), 40.0 (1.2), 42.8 (1.3), and 45.9 (1.1) at pressures of 30, 35, 40, 45, 50, 55, and 60, respectively ($p < 0.001$). Differences were significant between the resuscitators ($p = 0.02$) but too small to be considered important (< 3 L/min). Changes in lung compliance had no significant effect on the flow from the resuscitators ($p = 0.56$). **Conclusions**: The principal concern with O_2-powered resuscitators has been related to their high flows, and current AHA standards state that the flow from these devices should be 40 L/min. Our data indicate that the flow from O_2-powered resuscitators is dependent on their operating pressures. At low inlet pressures, as may occur with a faulty regulator, the related decrease in flow may seriously compromise volume delivery. At an inlet pressure of 30 psi and an inspiratory time of 1.5 s (as recommended by the AHA), V_T delivered will be 0.67 L (less than the 0.8 L recommended by the AHA). This low flow might also increase the work of breathing for a patient breathing spontaneously from the resuscitator. Respiratory care practitioners (RCPs) may use these devices infrequently during in-hospital resuscitation. However, because RCPs are frequently responsible for the training of other persons in emergency ventilation techniques (such as paramedics and EMTs), they should be familiar with the operation of these devices. Our data provide additional evidence to suggest re-evaluation of the use of O_2-powered resuscitators during CPR. When O_2-powered resuscitators are used, it is important that appropriate quality control measures be used to assure that the regulator is providing a pressure of 50 psi. (OF-91-031)

Use of the Fenem End-Tidal CO_2 Detector in Patients in Cardiac Arrest—David R Eitel MD, Dean Hess MEd RRT, Rodney Drawbaugh BS EMT-P, Cynthia Ogden BS. York Hospital, *York, Pennsylvania.*

The Fenem End-Tidal CO_2 Detector is a device that produces a discernible color change (purple to yellow) at $P_{etCO_2} > 2\%$ (15 torr at sea level). The principal manufacturer-suggested application of this device is to confirm endotracheal tube (ETT) position (tracheal vs esophageal). Previous work has shown that P_{etCO_2} is often very low during cardiac arrest, and that patients in cardiac arrest with an $P_{etCO_2} < 15$ torr are unlikely to be successfully resuscitated (JAMA 1989;262:1347-1351). **Study Question:** Is the Fenem P_{etCO_2} detector useful during cardiac arrest to predict the likelihood of successful resuscitation? **Methods**: The study population consisted of 30 patients in cardiac arrest in the field (median age 69 y, 23 men, 7 women). Following intubation and during bag-valve ventilation, the presence of cyclic inspiratory/expiratory color changes (purple/yellow) were noted on the Fenem. Correct ETT position was confirmed by visualization of the ETT passing through the vocal cords and clinical assessment (eg, auscultation of chest and epigastrium). All intubations were performed by prehospital ALS providers who were skilled in the technique of ET intubation. Return of spontaneous circulation (ROSC) was noted, and was defined as return of a palpable pulse and detectable blood pressure. **Results**: Cyclic color changes were noted on the Fenem in only 9 of the 30 cases (sensitivity for detection of tracheal intubation = 30%). ROSC occurred in 6 patients. The sensitivity of the Fenem for detection of ROSC was 83% (5/6), and the specificity was also 83% (20/24). The positive predictive value of the Fenem for detection of ROSC was only 56% (5/9), but the negative predictive value was 95% (20/21). In 3 cases, the Fenem was unusable after contamination with endotracheally instilled epinephrine or pulmonary edema fluid. **Conclusions**: Because of the low P_{etCO_2} levels that occur during cardiac arrest, cyclic color changes may not occur on the Fenem despite tracheal intubation. If contamination from drugs administered by the endotracheal route or pulmonary edema fluid is likely, the device should be temporarily removed from the airway. Failure of the Fenem to produce cyclic color changes in correctly intubated patients in cardiac arrest suggests that ROSC may be unlikely in these patients (negative predictive value of 95% for ROSC). Further work is needed in both the prehospital and inhospital environments to evaluate use of the Fenem to predict patients likely to have ROSC. (OF-91-034)

Evaluation of the Bauman and BagEasy Adult Manual Resuscitators—Thomas A Barnes EdD RRT, Northeastern University, *Boston, Massachusetts.*

The Bauman Disposable Adult Manual Resuscitator (General Medical Products Ltd, Santa Monica CA) is smaller than the BagEasy Adult Disposable Manual Resuscitator (Respironics Inc, Monroeville PA) (9.5 x 4.0 vs 15 x 4.5 in). The Bauman squeeze bag is approximately 1/2 the volume of BagEasy (1,250 vs 2,100 mL). Both units claim to deliver an average one-hand V_T of > 750 mL and are the only disposable resuscitators available with either a permanently attached PEEP or expiratory retard device. The Bauman has a manometer built into the device. **Method:** I tested the devices against the American Society for Testing and Materials (ASTM Standard F-920-85 Committee on Standards, Philadelphia, 1985:1-22) and International Organization for Standardization (ISO Standard 8382:1988{E} prepared by the Technical Committee ISO/TC

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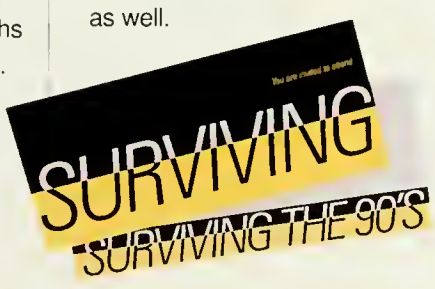

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121, Anaesthetic and Respiratory Equipment, ISO, New York, 1988:1-23) by using a lung model, the Bio-Tek VT-1 Ventilator Tester (Bio-Tek Instruments, Winooski VT). The VT-1 was set at a compliance of 0.02 L/cm H_2O [0.20 L/kPa] and a resistance of 20 cm H_2O/L/s [2 kPa/L/s] as specified by ASTM and ISO. **Results:** Both of the resuscitators met the ventilation requirements for V_T and f (600 mL x 20) and I:E < 1:1. Standard F-920 and Standard 8382 specify F_{DO_2} of ≥ 0.85 with attachments. Both met F-920 and 8382 standards for F_{DO_2} with attachments at 21°C (Bauman F_{DO_2} 0.85 and BagEasy F_{DO_2} 1.00). Only BagEasy could deliver the AHA-recommended V_T (800 mL), f (12/min), and I:E (< 1:2). Bauman delivered only 750 mL with a 2-hand maximum stroke volume delivered into the VT-1 as configured. Bauman had F_{DO_2} of 0.83 and 0.79 at higher minute volumes ($\dot{V}_E$) of 9.0 L/min (750 mL x 12/min) and 12 L/min (600 mL x 20/min). BagEasy had F_{DO_2} 1.00 at $\dot{V}_E$ 9.6 L/min (800 mL x 12/min) and 12 L/min (600 mL x 20/min). The Bauman resuscitator's F_{DO_2} was significantly lower in all three configurations (ANOVA, $p < 0.0001$). Both units passed the test for backward leakage; however, a substantial forward leak was observed with Bauman at V_T > 600 mL, which prevented the unit from delivering more than 750 mL when used to ventilate the VT-1. BagEasy did not have a forward leak. Both resuscitators passed the shock tolerance (1 meter drop to a concrete floor). The PEEP device on BagEasy when adjusted to "15" held 15 cm H_2O of end-expiratory pressure throughout the respiratory cycle and lesser amounts of PEEP also were held without loss of baseline pressure. The Bauman expiratory retard extended exhalation up to 6 s in the full "on" position when a 2-hand maximal stroke volume was delivered to the VT-1. Bauman was unable to maintain PEEP at any preset constant level. **Conclusion:** The smaller size of the Bauman ventilator appears to affect its ability to meet the AHA recommendation for V_T when used to ventilate a lung analog set at a low compliance and high resistance. The Bauman resuscitator may be a good choice when space is limited; however, practitioners should be aware of its limited F_{DO_2} and V_T capability. BagEasy remains the only disposable manual resuscitator with a true PEEP capability built into the unit. BagEasy appears to be a good choice when a large V_T and high F_{DO_2} with PEEP are required. Further study of the Bauman should be done to investigate the potential of its expiratory retard. (OF-91-158)

Ventilatory Volumes Using Mouth-to-Mouth, Bag-Valve-Mask, and Pocket Face Mask—Thomas A Barnes EdD RRT, Gavin Adams BS CRTT, Northeastern University, *Boston, Massachusetts.*

The volumes delivered to a resuscitation mannequin were compared using mouth-to-mouth (MO/MO), bag-valve-mask (BVM), and a one-piece silicone (surgical-type) pocket mask that has a central airway leading to a one-way valve (Kiss of Life, KOL, Brunswick Biomedical Technologies Inc, Wareham MA). Skill with each device was checked against the AHA recommendation of 12 ventilations/min, each with V_T ≥ 800 mL. **Method:** We assessed the ability of 10 respiratory therapy students to ventilate a Laerdal Recording Resusci Anne calibrated with a supersyringe so that the green feedback light flashed when a 800-mL V_T was delivered. All 10 students had been certified in BCLS (5 within the last 8 mo). Each ventilatory technique was evaluated in three segments: (1) practice with the green feedback light visible, (2) 2-min assessment with chest compressions without feedback from green light, and (3) 10-min 'settling in' assessment with chest compressions without feedback. A 2-person CPR ratio of 5:1 compressions to ventilation with 12 ventilations/min was delivered to the mannequin. The number of 800-mL V_Ts delivered/min was recorded. In the first segment, the number of tries to achieve a successful 800-mL V_T was recorded. BVM was done with a Code Blue adult manual resuscitator using the FATS (face-and-thigh system) approach described by Cummins (Ann Emerg Med 1986;15:1187-1192). **Results:**

	MO/MO	BVM	KOL
Practice tries*	1.5 (0.8)	1.6 (0.8)	5.3 (5.3)
2-min assess†	10.8 (2.9)	9.1 (4.5)	5.3 (5.1)
10-min assess†	9.8 (3.8)	8.3 (4.2)	4.0 (4.2)

*Mean (SD) practice tries before a successful 800 mL ventilation.
†All values are mean (SD) successful 800 mL V_T/min.

No significant differences existed between MO/MO and BVM during practice, 2-min assessment, and 10-min assessment (ANOVA, $p = 0.81, 0.33, 0.39$, respectively). Significant differences existed between practice tries when the KOL was compared to MO/MO and BVM (ANOVA, $p < 0.05$) and between 10-min assessments when the KOL was compared to MO/MO and BVM (ANOVA, $p < 0.01$ and $p < 0.05$, respectively). **Conclusions:** BVM can be used to deliver 800 mL V_T at a success rate very close to that achieved with MO/MO when the FATS approach is used. It appears that it is difficult to meet the AHA V_T recommendation using the KOL pocket face mask. More study is needed on the size of the V_T delivered with the KOL device. (OF-91-159)

An Evaluation of the Esophageal Detector Device—Douglas Oberly CRTT, Scott Stein, Dean Hess MEd RRT, David Eitel MD, Mark Simmons MS RPFT RRT, York Hospital, *York, Pennsylvania.*

Esophageal intubation is a serious complication if unrecognized. Although P_{etCO_2} is the recognized standard for detection of esophageal intubation, this method is unreliable during cardiac arrest when P_{etCO_2} is very low. An esophageal detector device (EDD) has been described to detect esophageal intubation (Anaesthesia 1989;44:412). The EDD consists of a syringe or squeeze bulb that generates a negative pressure on the ETT. If the ETT is placed in the trachea, gas can be aspirated with minimal resistance; if it is placed in the esophagus, gas cannot be withdrawn and a negative pressure or resistance is produced. We have had the opportunity to evaluate the patented prototype of a squeeze-bulb EDD (SuctionEasy, Respironics, Murrysville PA). **Study Question:** Does the EDD reliably differentiate between esophageal and tracheal intuba-

tion? **Methods**: Following the approval of our Institutional Review Committee, the study was conducted in the Emergency Department using 10 recently deceased subjects (9 men, 1 woman, age 50-72 y). An 8-mm-ID ETT was placed orally into the trachea, and a second 8-mm-ID tube was placed orally into the esophagus. Both tubes extended the same distance from the mouth. The tube cuffs were not inflated. The tubes were randomly marked as A or B so that the evaluators would not know which tube was in the trachea and which was in the esophagus. After tube placement, the EDD was used by ALS providers (physicians, nurses, paramedics, respiratory therapists) to determine whether a tube was in the trachea or the esophagus. Evaluators had been instructed in the use of the EDD prior to participation in the study, were not present when the tubes were placed, and were permitted 1 trial/subject. Multiple evaluators were allowed for each subject. The bulb of the EDD was squeezed by the evaluator who then attached it to the ETT. The bulb inflation rate was assessed by the evaluator as immediate inflation, delayed inflation, or no inflation and the findings recorded. **Results**: A total of 45 trials were performed on the subjects (median 4 evaluations/subject, range 1-8). For the tracheal tube, the EDD inflated immediately in all cases; it was thus 100% correct in identification of tracheal intubation. For the esophageal tube, the EDD did not inflate in 44 cases, and in one case it filled with vomitus; it thus correctly indicated esophageal intubation in all cases. In none of the cases did the EDD have a delayed inflation. All evaluators indicated that the EDD was simple and easy to use. **Conclusions**: In this study using deceased subjects, the EDD correctly indicated tracheal and esophageal intubation in all cases. It was simple to use and is inexpensive. Further work is needed to evaluate the usefulness of this device in determination of correct ETT placement in patients following emergency intubation. (OF-91-035)

Altitude and Temperature Effects on Bag-Mask Resuscitator Performance—D Theron Van Hooser MEd RRT, Venco Institute for Oxygen Therapy, *Denver, Colorado;* Tammi Kewatz AA CRTT, Mountainview Hospital, *Payson, Utah*; Karen Lenz AA CRTT, Mc Kay Dee Hospital, *Ogden, Utah.*

Study Question: How do altitude, temperature, storage location, and use of 2 hands affect volume and rate delivery capability of 9 different brands of disposable and 6 different brands of nondisposable resuscitators, as utilized by the National Ski Patrol? **Method:** This study was done in two parts—Part I in winter 1989-90, Part II in winter 1990-91. Ski patrollers and respiratory care practitioners trained and familiar with equipment function volunteered to perform data collection. Stroke volume, minute volume, and maximum rates were collected in a Bio-Tek VT-1 lung analog with compliance set at 0.02 L/cm H_2O [0.2 L/kPa] and parabolic resistor r20 in line. Data were collected in the lab and on the mountaintop at the ski-patrol shelter. Conditions were Part I lab 22°C, altitude 6,520 ft; mtn -18°C, altitude 10,450 ft. Part II lab was 22°C and mtn -14 C. Order was random, and all bags were squeezed without gloves. **Results:** Using matched and unmatched *t* tests, we found that there was no significant difference in rate ($p = 0.298$) or stroke volume ($p = 0.438$) capabilities between disposable and nondisposable in the lab in either part of the study; however, at the mountaintop, rates were significantly reduced ($p < 0.001$), while the stroke volume remained the same. Mountaintop conditions also affected the minute volume ($p < 0.001$). In Part II some of the same bags were tested, and the mountaintop conditions were warmer. No significant rate difference existed between the disposable and nondisposable groups ($p = 0.852$). Stroke and minute volumes were also not significantly different ($p = 0.784$ and 0.215, respectively). In both parts, use of two hands made significant differences in ability to deliver tidal volumes ($p < 0.001$ by ANOVA). Site did not affect the tidal volumes but did affect the rate capabilities. **Conclusions:** Significant decreases in rate (hence minute volume) were caused by temperature but not altitude. Tidal volumes were essentially the same in both locations for both groups of bags. Two-handed use delivers greater volumes in both locations and should be used for actual resuscitation. All bags (disposable and nondisposable) should be stored indoors prior to use. (OF-91-121)

Ventilatory Modes, Systems, and Vagaries

Effects of Working Pressure (WP) and Endotracheal Tube Size on Gas Delivery during Pressure-Support Ventilation (PSV) with the Servo 900C—Arthur A Taft MHS RRT, Franklin H Dennison MEd RRT. Medical College of Georgia, *Augusta, Georgia.*

We studied the effects of varying working pressure (WP) on peak flow (PF) and tidal volume delivery ($V_{T\text{-del}}$) through different-sized endotracheal tubes (ETTs) during pressure-support ventilation (PSV) using the Servo 900C. We used a previously described lung model (Chest 1985;88:519-526). The TTL model was further modified to allow placement of a #2 Fleisch pneumotach at the lung inlet to measure delivered flows and the volumes distal to various-sized ETTs. Patient breath initiation was simulated with an MA 2+2 ventilator (f 17, $\dot{V}$40 L/min, V_T 100 mL). PSV level (30 cm H_2O) and test lung compliance (0.03 L/cm H_2O) were constant throughout the experiment. All data were collected with an MI-2 signal processing center interfaced with a Zenith 386 microprocessor. WP was varied in 5-cm H_2O increments from 45 to 115 cm H_2O (although all aren't shown) for each different ETT size (6.0, 7.0, 8.0, 9.0 mm ID).

Tube Size	Variable	Working Pressure (cm H_2O) 45	55	65	75
6.0	$V_{T\text{-del}}$ (mL)	781 (0.75)	756 (0.79)	749 (2.16)	756 (2.56)
	PF (L/min)	63 (0.34)	69 (0.32)	71 (0.58)	72 (0.68)
7.0	$V_{T\text{-del}}$ (mL)	786 (0.74)	749 (1.63)	696 (1.94)	688 (3.45)
	PF (L/min)	71 (0.38)	82 (0.58)	86 (0.64)	89 (0.55)
8.0	$V_{T\text{-del}}$ (mL)	822 (0.72)	790 (0.83)	792 (1.21)	781 (2.06)
	PF (L/min)	74 (0.31)	97 (0.60)	103 (0.83)	107 (0.78)
9.0	$V_{T\text{-del}}$ (mL)	843 (0.53)	829 (0.47)	826 (0.97)	798 (1.82)
	PF (L/min)	86 (0.41)	107 (0.39)	117 (1.41)	123 (1.16)

Tube Size	Variable	Working Pressure (cm H_2O) 45	55	65	75
6.0	$V_{T\text{-del}}$ (mL)	755 (1.38)	755 (3.23)	744 (4.51)	740 (2.79)
	PF (L/min)	71 (0.62)	73 (0.53)	73 (0.87)	74 (0.61)
7.0	$V_{T\text{-del}}$ (mL)	690 (3.17)	696 (4.46)	696 (3.54)	693 (3.12)
	PF (L/min)	91 (0.65)	92 (0.81)	91 (0.83)	92 (0.69)
8.0	$V_{T\text{-del}}$ (mL)	778 (0.61)	764 (2.75)	771 (1.26)	759 (3.12)
	PF (L/min)	113 (1.27)	117 (1.37)	122 (1.77)	120 (1.95)
9.0	$V_{T\text{-del}}$ (mL)	789 (3.14)	784 (0.75)	783 (1.77)	786 (2.45)
	PF (L/min)	128 (1.75)	133 (1.55)	136 (2.08)	138 (2.22)

Note: All values are reported as mean (SEM); n = 15 for all groups.

Statistical analysis by ANOVA revealed a significant interaction between WP and $V_{T\text{-del}}$ and PF in all ETT sizes ($p < 0.001$), although the effects of WP with the 6.0-mm ETT were less pronounced than those of the other ETT sizes. $V_{T\text{-del}}$ decreased and PF increased as WP was increased. A significant interaction was seen between ETT size and $V_{T\text{-del}}$ and PF ($p < 0.001$). PF decreased as ETT size decreased. $V_{T\text{-del}}$ tended to decrease with ETT size except in the 6.0-mm ETT, which unexpectedly showed larger volumes at higher WPs than the 7.0-mm ETT. These results indicate that when using PSV with the Servo 900C, WP and ETT size will influence PF and $V_{T\text{-del}}$; but in a 6.0-mm ETT, changing WP has little effect. They further indicate that increasing WP may help meet high patient flow demands but may also require increasing PSV level to maintain $V_{T\text{-del}}$. In a patient with low flow demands, decreasing WP may increase $V_{T\text{-del}}$. Further studies are needed to determine how adjusting WP will affect gas delivery through smaller-sized ETTs as well as at varying PSV levels, and how WP may affect imposed work of breathing during PSV, especially in the presence of high inspiratory flow demands and large V_Ts. (OF-91-019)

Effects of High Inspiratory Flow Demands on Pressure-Support Ventilation—Franklin H Dennison MEd RRT, Arthur A Taft MHS RRT. Medical College of Georgia, *Augusta, Georgia.*

Using a training test lung (TTL) (Chest 1985;88:519-526), we studied the effects of high spontaneous flow demands on pressure-support ventilation (PSV) as working pressure (WP) was varied in 10-cm H_2O increments from 50-110, using the Servo 900C. Results were compared to conditions of minimal spontaneous flow demand (F_{min}). **Hypothesis:** Under conditions of high flow demand, peak inspiratory flowrate and V_T delivered ($V_{T\text{-del}}$) by the test ventilator would increase as WP was increased. Patient flow demand (F_{dem}) was simulated with an MA 2+2 ventilator by setting demand tidal volume ($V_{T\text{-dem}}$) at 80% (±5%) of the V_T delivered by the Servo 900C. Demand flowrates on the MA 2+2 were set at 60, 80, and 100 L/min (± 5%). We set the V_T at 100 mL and flow at 40 L/min for F_{min}. We modified the TTL so that a #2 Fleisch pneumotach could be placed at the lung inlets to measure demand and delivered flowrates. Lung compliance for each lung was set at 0.03 L/cm H_2O, and the ventilator circuit was attached to a 9.0-mm ETT. The PS level (PSL) on the Servo was set at 30 cm H_2O and sensitivity at -2 cm H_2O throughout the study. An MI-2 signal processing center interfaced with a Zenith 386 microprocessor was used for data acquisition and flow-volume integration. Statistical analysis by ANOVA showed significant interaction between WP, $V_{T\text{-del}}$, and peak flow (PF) ($p < 0.001$). As hypothesized, PF delivery (F_{del}) increased with an increase in WP for all flow demands. Volume delivery decreased with increases in WP. **Results:**

F_{dem} (L/min)	F_{del} (L/min)	SD	% increase	$V_{T\text{-del}}$	SD	% decrease
F_{min}	102-139	6.7	36.3	832-785	5.7	5.6
60	104-143	4.6	37.5	836-790	7.8	5.4
80	108-148	6.1	37.0	827-766	8.9	7.4
100	116-159	4.6	37.0	820-766	5.4	6.6

Data indicate that altering WP has similar effects on PF and V_T irrespective of flow demands. These data are clinically important, suggesting that under conditions of stress an elevation in patient inspiratory flow demand can be better met by increasing the level of WP. There may be some risk of compromising patient ventilation due to the reduction in $V_{T\text{-del}}$, but this can easily be compensated for by increasing the PSL. We believe further research is needed to measure work of breathing and gas exchange under conditions of high flow demand and poor lung compliance before pressure support can be considered a primary mode of ventilation in the intensive care setting. (OF-91-020)

Evaluation of the Bird 7001 Ventilator under Hyperbaric Conditions—John L VanRynen RN RRT. Medical College Hospitals, *Toledo, Ohio.*

A hyperbaric ventilator must be capable of optimal function in spite of increasing ambient pressure and gas density (D). The Bird 7001 ventilator meets this criteria via utilization of inspiratory flow acceleration (IFA), expiratory flowrate (EF), and a secondary gas source from an entrainment reservoir bag (ERB). **Method:** A Bird 7001 ventilator was mounted in our hyperbaric chamber connected to a Manley lung simulator via an IPPB circuit. Compliance was 50 mL/cm H_2O, resistance 8 cm H_2O/L/s. f, V_T, t_i, and PIP were adjusted for baseline settings of 12, 800 mL, 1.0 s, and 24-30 cm H_2O, then monitored via Wright Respirometer and stopwatch throughout 6 test dives ranging from 1 to 6 atmospheres absolute (ATA) pressure (1 ATA = 760 torr). Compressed air, O_2, and 80-20 heliox were used to power the 7001. Drive pressure was maintained at a gradient of 50 psig over ambient pressure during compression. **Results:** t_i lengthened (> 1.5 s) as D increased but could be adjusted back to baseline by use of IFA and ERB. Tests beyond 4 ATA required heliox to decrease the D of the carrier gas, thereby allowing t_i to approach baseline (< 1.5 s). Use of the EF removed back pressure from the IPPB circuit. f, V_T, and PIP could also be adjusted back to, or near, baseline (< 10% change) when final driving pressures were reached, as long as t_i remained near baseline. **Conclusions:** Our tests indicate (1) the Bird 7001 ventilator is effective as a hyperbaric ventilator up to 6 ATA; (2) maintenance of t_i at baseline is critical for optimal ventilation under pressure; and (3) using the IFA, EF, and ERB incorporated in the 7001 allows satisfactory compensation for increases in D. Our clinical experiences with

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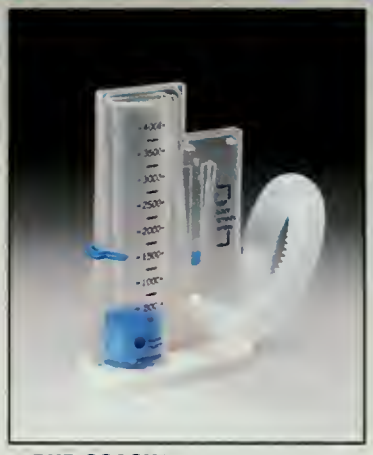

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over 200 cases during the past 5 years have proven the stated findings to be true. We therefore recommend the Bird 7001 ventilator for use in the hyperbaric environment. (OF-91-044)

Flow-Resistive Characteristics of 4 Threshold Resistor Expiratory Positive Pressure (EPP) Valves—Harald Mang MD, Sylvester Barker, Mary C Cyeyk-Chapman BS RRT, Robert M Kacmarek PhD RRT. Massachusetts General Hospital, *Boston, Massachusetts.*

Introduction: To apply CPAP, threshold resistor EPP valves are recommended to stabilize EPP level and to minimize the imposed work of breathing (WOBimp). **Methods & Materials:** Using a training test lung (TTL), we measured peak expiratory pressure (PEP), peak sub-baseline inspiratory pressure (PSIP), and WOBimp in 4 EPP valves (Ambu PEEP 20, Intertec Inspiron, Respironics, Vital Signs) during simulated spontaneous breathing (SP). A Puritan-Bennett 7200 was used to power one chamber of the TTL, which caused the other chamber to rise simulating SP (V_T 0-4 L, I:E 1:2, peak flow 40 L/min, f 20). We tested 5 valves of each type at 3 CPAP levels (5, 10, and 15 cm H_2O) and 3 continuous-flow CPAP system flow settings (30, 50, and 70 L/min). Inspiratory WOBimp (inWOBimp) was defined as the area of the pressure-volume loop between a vertical line at the system's CPAP level and that part of the curve established by pressures below CPAP level. Expiratory WOBimp (exWOBimp) was calculated by subtracting inspiratory WOBimp from total WOBimp/breath. For each condition, 3 breaths were measured and averaged. **Results:** We report mean (SD) results at 10 cm H_2O CPAP and 50 L/min system flow. Data at other settings were consistent with trends noted below.

valve PSIP	(cm H_2O)	inWOBimp (J/L)	PEP (cm H_2O)	exWOBimp (J/L)
Ambu	4.13 (0.23)	0.37 (0.03)	2.07 (0.27)	0.11 (0.03)
Intertec	5.51 (0.50)	0.39 (0.03)	1.95 (0.23)	0.15 (0.02)
Respironics	3.82 (0.36)	0.33 (0.02)	1.92 (0.07)	0.13 (0.01)
Vital Signs	3.44 (0.14)	0.32 (0.42)	2.40 (0.22)	0.15 (0.03)

Experience: There were no operational problems with the Ambu and Vital Signs valves. The Intertec Inspiron and Respironics valves had grossly inaccurate markings, whistled throughout, and occasionally fell apart. **Conclusion:** We demonstrated qualitative as well as quantitative differences in the flow-resistive characteristics of EPP valves that influence patient comfort and effort, and may be significant during CPAP weaning. (OF-91-092)

Accurate Bedside Measurement of Intrinsic PEEP during Mechanical Ventilation—Nancy Thurman Tendal BS RCP RRT, David M Burns MD, F Wayne Johnson RCP RCPT, Richard M Ford BS RCP RRT. UC-San Diego Medical Center, *San Diego, California.*

Introduction: The development of positive end-expiratory pressure (PEEP) at this alveolar level due to insufficient expiratory time is termed intrinsic PEEP (PEEPi). We evaluated the accuracy of a device used clinically to measure intrinsic PEEP by comparing measurements made within a test lung (true PEEPi) to those made at the airway opening (measured PEEPi). The device consists of an open elbow with a removable cap and one-way valve to prevent back flow and is placed in the inspiratory circuit at the Y connector. The cap is removed during the expiratory phase, diverting inspiratory gas to the atmosphere. The one-way valve is placed distal to the elbow valve and closes the remaining ventilator circuit from the airway opening to the exhalation valve allowing alveolar and airway pressures to come to equilibrium. **Method:** A test lung with a defined compliance was ventilated through a 5-mm-ID endotracheal tube to produce a consistent resistance using a Puritan-Bennett 7200a ventilator. Pressures were measured in the test lung and at the airway opening using a differential pressure transducer and were observed on the ventilator pressure manometer. Levels of PEEPi from 0-40 cm H_2O were produced by ventilating the test lung with varying f and I:E. **Results:** There is a marginally lower but significant difference between the value observed on the ventilator pressure manometer and the value measured using the differential pressure transducer at the airway opening ($p < 0.5$). However, the maximum difference recorded was 2 cm H_2O, which was not felt to be clinically significant. **Experience:** The measured PEEPi using the elbow configuration of the valve and expiratory-hold maneuver matched the true PEEPi up to an intrinsic PEEP of approximately 23 cm H_2O. The underestimation of PEEPi may be caused by a transfer of gas from the lung to the ventilator tubing during the expiratory-hold maneuver. **Conclusion:** The use of the valved elbow provides a clinically useful method for measurement of PEEPi up to a level of approximately 23 cm H_2O. At pressures > 23 cm H_2O, the PEEPi reflected on the ventilator manometer may underestimate the true PEEPi. (OF-91-096)

Compliance Characteristics of Adult Ventilator Circuits—Robert S Campbell RRT, Richard D Branson RRT, James W Osler. University of Cincinnati Medical Center, *Cincinnati, Ohio.*

Introduction: Compressible volume (CV) within ventilator systems affects V_T delivery and measurement. Volume is compressed inside the ventilator, humidifier, and breathing circuit (BC) and is a function of ventilation pressure, tubing distensibility, and total volume of the system. **Method & Materials:** We measured the compliance (C_L) of 17 BCs: 3 non-disposable (ND), 3 heated wire (HW), and 11 disposable (D) at room temperature (24°C) and at 34°C. 3 of each BC were tested. C_L was measured by injecting volume in 100-mL increments into the BC (with all ports capped) from a calibration syringe until pressure exceeded 120 cm H_2O. Pressure was continuously measured with an RT-200 calibration analyzer. **Results:** The table shows mean (SD) C_L for each BC at 24°C and 34°C.

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INDICATIONS AND USAGE

SURVANTA is indicated for prevention and treatment ("rescue") of Respiratory Distress Syndrome (RDS) (hyaline membrane disease) in premature infants. SURVANTA significantly reduces the incidence of RDS, mortality due to RDS and air leak complications.

Prevention

In premature infants less than 1250 g birth weight or with evidence of surfactant deficiency, give SURVANTA as soon as possible, preferably within 15 minutes of birth

Rescue

To treat infants with RDS confirmed by x-ray and requiring mechanical ventilation, give SURVANTA as soon as possible, preferably by 8 hours of age

CONTRAINDICATIONS

None known

WARNINGS

SURVANTA is intended for intratracheal use only

SURVANTA CAN RAPIDLY AFFECT OXYGENATION AND LUNG COMPLIANCE Therefore, its use should be restricted to a highly supervised clinical setting with immediate availability of clinicians experienced with intubation, ventilator management, and general care of premature infants. Infants receiving SURVANTA should be frequently monitored with arterial or transcutaneous measurement of systemic oxygen and carbon dioxide

DURING THE DOSING PROCEDURE, TRANSIENT EPISODES OF BRADYCARDIA AND DECREASED OXYGEN SATURATION HAVE BEEN REPORTED If these occur, stop the dosing procedure and initiate appropriate measures to alleviate the condition. After stabilization, resume the dosing procedure

PRECAUTIONS

General

Rales and moist breath sounds can occur transiently after administration. Endotracheal suctioning or other remedial action is not necessary unless clear-cut signs of airway obstruction are present

Increased probability of post-treatment nosocomial sepsis in SURVANTA-treated infants was observed in the controlled clinical trials (Table 3) The increased risk for sepsis among SURVANTA-treated infants was not associated with increased mortality among these infants The causative organisms were similar in treated and control infants There was no significant difference between groups in the rate of post-treatment infections other than sepsis

Use of SURVANTA in infants less than 600 g birth weight or greater than 1750 g birth weight has not been evaluated in controlled trials There is no controlled experience with use of SURVANTA in conjunction with experimental therapies for RDS (eg, high-frequency ventilation or extracorporeal membrane oxygenation).

No information is available on the effects of doses other than 100 mg phospholipids/kg, more than four doses, dosing more frequently than every 6 hours, or administration after 48 hours of age

Carcinogenesis, Mutagenesis, Impairment of Fertility

Reproduction studies in animals have not been completed Mutagenicity studies were negative Carcinogenicity studies have not been performed with SURVANTA

ADVERSE REACTIONS

The most commonly reported adverse experiences were associated with the dosing procedure In the multiple-dose controlled clinical trials, transient bradycardia occurred with 11.9% of doses Oxygen desaturation occurred with 9 8% of doses

Other reactions during the dosing procedure occurred with fewer than 1% of doses and included endotracheal tube reflux, pallor, vasoconstriction, hypotension, endotracheal tube blockage, hypertension, hypocarbia, hypercarbia, and apnea No deaths occurred during the dosing procedure, and all reactions resolved with symptomatic treatment

The occurrence of concurrent illnesses common in premature infants was evaluated in the controlled trials. The rates in all controlled studies are in Table 3

TABLE 3

	All Controlled Studies		
Concurrent Event	SURVANTA (%)	Control (%)	P Value[a]
Patent ductus arteriosus	46 9	47 1	0 814
Intracranial hemorrhage	48 1	45 2	0 241
Severe intracranial hemorrhage	24 1	23 3	0 693
Pulmonary air leaks	10 9	24 7	< 0 001
Pulmonary interstitial emphysema	20 2	38 4	< 0 001
Necrotizing enterocolitis	6 1	5 3	0 427
Apnea	65 4	59 6	0 283
Severe apnea	46 1	42 5	0 114
Post-treatment sepsis	20 7	16 1	0 019
Post-treatment infection	10 2	9 1	0 345
Pulmonary hemorrhage	7 2	5 3	0 166

[a] P value comparing groups in controlled studies

When all controlled studies were pooled, there was no difference in intracranial hemorrhage However, in one of the single-dose rescue studies and one of the multiple-dose prevention studies, the rate of intracranial hemorrhage was significantly higher in SURVANTA patients than control patients (63 3% *v* 30 8%, $P = 0.001$, and 48.8% *v* 34 2%, $P = 0.047$, respectively). The rate in a Treatment IND involving approximately 4400 infants was lower than in the controlled trials

In the controlled clinical trials, there was no effect of SURVANTA on results of common laboratory tests white blood cell count and serum sodium, potassium, bilirubin, creatinine

More than 3700 pretreatment and post-treatment serum samples were tested by Western Blot immunoassay for antibodies to surfactant-associated proteins SP-B and SP-C. No IgG or IgM antibodies were detected

Several other complications are known to occur in premature infants. The following conditions were reported in the controlled clinical studies. The rates of the complications were not different in treated and control infants, and none of the complications were attributed to SURVANTA

Respiratory lung consolidation, blood from the endotracheal tube, deterioration after weaning, respiratory decompensation, subglottic stenosis, paralyzed diaphragm, respiratory failure

Cardiovascular: hypotension, hypertension, tachycardia, ventricular tachycardia, aortic thrombosis, cardiac failure, cardiorespiratory arrest, increased apical pulse, persistent fetal circulation, air embolism, total anomalous pulmonary venous return

Gastrointestinal: abdominal distention, hemorrhage, intestinal perforations, volvulus, bowel infarct, feeding intolerance, hepatic failure, stress ulcer.

Renal renal failure, hematuria

Hematologic: coagulopathy, thrombocytopenia, disseminated intravascular coagulation

Central Nervous System seizures

Endocrine/Metabolic: adrenal hemorrhage, inappropriate ADH secretion, hyperphosphatemia

Musculoskeletal inguinal hernia

Systemic: fever, deterioration.

Follow-Up Evaluations

To date, no long-term complications or sequelae of SURVANTA therapy have been found

Single-Dose Studies

Six-month adjusted-age follow-up evaluations of 232 infants (115 treated) demonstrated no clinically important differences between treatment groups in pulmonary and neurologic sequelae, incidence or severity of retinopathy of prematurity, rehospitalizations, growth, or allergic manifestations

Multiple-Dose Studies

Six-month adjusted age follow-up evaluations have not been completed Preliminarily, in 605 (333 treated) of 916 surviving infants, there are trends for decreased cerebral palsy and need for supplemental oxygen in SURVANTA infants. Wheezing at the time of examination tended to be more frequent among SURVANTA infants, although there was no difference in bronchodilator therapy

Twelve-month follow-up data from the multiple-dose studies have been completed in 328 (171 treated) of 909 surviving infants To date no significant differences between treatments have been found, although there is a trend toward less wheezing in SURVANTA infants in contrast to the six month results

OVERDOSAGE

Overdosage with SURVANTA has not been reported Based on animal data, overdosage might result in acute airway obstruction Treatment should be symptomatic and supportive

Rales and moist breath sounds can transiently occur after SURVANTA is given, and do not indicate overdosage Endotracheal suctioning or other remedial action is not required unless clear-cut signs of airway obstruction are present

HOW SUPPLIED

SURVANTA (beractant) Intratracheal Suspension is supplied in single-use glass vials containing 8 mL of SURVANTA (NDC 0074-1040-08). Each milliliter contains 25 mg of phospholipids (200 mg phospholipids/8 mL) suspended in 0 9% sodium chloride solution The color is off-white to light brown

Store unopened vials at refrigeration temperature (2-8°C) Protect from light Store vials in carton until ready for use Vials are for single use only Upon opening, discard unused drug

June, 1991

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BC	C_L (mL/cm H_2O) 24°C	34°C
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Hudson (ND)	3.24 (0.2)	3.54 (0.3)
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Hudson (HW)	1.79 (0.2)	2.04 (0.2)
Baxter (HW)	1.79 (0.3)	1.96 (0.2)
King (D)	1.84 (0.1)	1.99 (0.2)
Vital Signs (D)	2.19 (0.2)	2.37 (0.3)
Hudson (D)	1.78 (0.1)	1.84 (0.2)
Marquest (D)	2.25 (0.3)	2.39 (0.3)
Baxter (D)	1.98 (0.1)	2.17 (0.2)
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Inspiron (D)	2.41 (0.3)	2.46 (0.3)
Inhalation Plastics (D)	1.87 (0.1)	2.29 (0.2)
Puritan-Bennett (D)	1.68 (0.1)	1.96 (0.2)
Artec (D)	1.54 (0.2)	1.63 (0.3)
Seamless (D)	2.77 (0.2)	2.82 (0.3)

Mean C_L differs between BCs by as much as 1.73 mL/cm H_2O at 24°C and by 1.91 mL/cm H_2O at 34°C. Heating the BCs caused a mean (SD) change in C_L of 0.21 (0.07) (about 5%). **Conclusions:** C_L characteristics of BCs vary among manufacturers due to differences in materials. Changes in C_L of BCs due to heating are small (range 0.01-0.54 mL/cm H_2O). C_L of ND BCs are almost twice that of D BCs. Practitioners should be aware of the C_L characteristics of BCs because it may affect delivered V_T during mechanical ventilation. (OF-91-138)

Resistance Characteristics of Adult Ventilator Circuits—James W Osler, Richard D Branson RRT, Robert S Campbell RRT. University of Cincinnati Medical Center, *Cincinnati, Ohio.*

Introduction: Patient work of breathing (WOB) during mechanical ventilation can be affected by the ET tube, humidifier, and breathing circuit (BC). **Methods & Materials:** To define the contribution of the BC, we determined the pressure drop (PD) across 17 BCs: 3 nondisposable (ND), 3 heated wire (HW), and 11 disposable (D) at flowrates of 0.5, 1.0, 1.5, and 2.0 L/s. 3 of each BC were tested with and without the elbow adapter (EA). Room air was drawn through the inspiratory limb (IL) of the BC by a vacuum source and flow measured by a Fisher-Porter flowmeter. PD was measured with an RT-200 calibration analyzer. Pressure taps were placed at the patient and inspiration ends, and the expiration port was capped. **Results:**

BC	PD at 0.5 L/s c elbow	s elbow	PD at 1.5 L/s c elbow	s elbow
Puritan-Bennett (ND)	0.49 (0.01)	-	5.4 (0.03)	-
Bear (ND)	0.30 (0.01)	-	3.2 (0.02)	-
Hudson (ND)	0.40 (0.01)	0.21 (0.01)	4.0 (0.05)	2.2 (0.02)
Marquest (HW)	0.40 (0.02)	0.29 (0.02)	3.7 (0.06)	2.7 (0.04)
Hudson (HW)	0.78 (0.04)	0.56 (0.03)	7.2 (0.04)	5.4 (0.08)
Baxter (HW)	0.43 (0.02)	0.29 (0.01)	4.2 (0.04)	2.9 (0.06)
King (D)	0.34 (0.02)	0.17 (0.01)	3.6 (0.04)	1.7 (0.01)
Vital Signs (D)	0.33 (0.01)	0.14 (0.01)	3.4 (0.02)	1.7 (0.02)
Hudson (D)	0.41 (0.01)	0.22 (0.01)	3.9 (0.05)	2.1 (0.03)
Marquest (D)	0.43 (0.02)	0.30 (0.01)	4.0 (0.60)	2.9 (0.03)
Baxter (D)	0.30 (0.01)	-	3.1 (0.02)	-
Novaventrx (D)	0.46 (0.03)	-	4.6 (0.04)	-
Inspiron (D)	0.37 (0.02)	0.29 (0.02)	3.6 (0.02)	2.8 (0.03)
Inhalation Plastics (D)	0.28 (0.01)	0.18 (0.01)	2.5 (0.01)	1.8 (0.01)
Puritan-Bennett (D)	0.44 (0.02)	0.29 (0.01)	4.8 (0.06)	3.4 (0.04)
Artec (D)	0.30 (0.01)	0.20 (0.01)	2.8 (0.02)	1.5 (0.01)
Seamless (D)	0.37 (0.02)	0.23 (0.01)	3.6 (0.01)	2.3 (0.02)

Conclusions: Our results demonstrate that (1) PD across BCs increases when an elbow adapter is used, (2) PD varies between BCs due to diameter and shape of the Y piece, (3) PD was greatest in the Hudson HW due to presence of 4 wires in the IL, and (4) PD at 1.5 L/s may adversely affect patient WOB. Purchase of a BC should include consideration of resistive characteristics. (OF-91-139)

Equipment Testing and Evaluation

Body Plethysmograph Modification: Evaluation as an Altitude Chamber—Patricia Walters RPFT RRT, Lela Brink MD, Curt Streichert CRTT, Glenn Wright CBET. Children's Medical Center of Dallas, *Dallas, Texas.*

We evaluated modifications to PK Morgan Body Plethysmograph Model 089 (box) to function as an altitude chamber. This model box contains an accessory port with removable plug 3.6 cm in diameter. A black rubber stopper of same diameter was used to replace plug. Silicone oil was used to lubricate drill bit, and two holes were drilled into stopper to match diameter of 65-cm length of O_2 tubing and 150-cm length of Baxter Medi-Vac connective tubing. Both lines were forced midway through stopper and leaks were sealed with silicone glue. The stopper was then used to seal accessory port. Both lines were allowed to dangle freely inside box. The external end of O_2 tubing was attached to low pressure port of a Magnehelic manometer and connective tubing was attached to wall vacuum with Vacutron Suction Regulator. Princo Fortin Type Mercurial Barometer and 72-kg male (to maintain calibration of barometer's cistern reservoir) were placed inside box. Doors were pneumatically shut and vent was set in closed position on box controller. Five minutes were given for thermal stabilization before any measurements were taken. Wall vacuum was set at -200 torr and allowed to run continuously until negative pressure inside box read -20, -40, -60, -80, and -100 cm H_2O on manometer. The cistern reservoir was checked before each reading. Readings were taken at ambient pressure and all five levels of negative pressure. All PB readings were corrected to temperature and rounded off to nearest whole number. Average corrected barometric pressure (PB) (in torr) for each level of negative pressure (in cm H_2O) was 732 for -20, 717 for -40, 700 for -60, 683 for -80, and 670 for -100. No special supplies were purchased for modification. We conclude that the box was effectively modified to function as an altitude chamber

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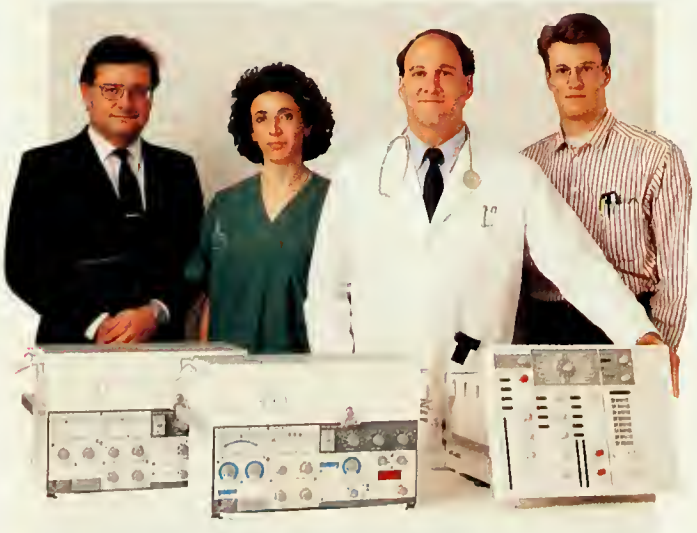

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producing lower levels of PB as negative pressure was applied, without harming normal box operation. As an altitude chamber applications include use as an educational tool in training air transport personnel and in evaluating respiratory therapy equipment. (OF-91-083)

Polarographic Analysis of Oxygen at Low Barometric Pressure: A Simulation—Lela Brink MD, Patricia Walters RPFT RRT, Children's Medical Center, *Dallas, Texas.*

Polarographic O_2 analyzers (POAs) measure P_{O_2} even though their displays are interpreted as $\%O_2$. During air transports, barometric pressure (PB) and P_{O_2} decrease from ground measurements while $\%O_2$ remains constant. POAs will read a lower $\%O_2$ while actually measuring the lower P_{O_2}. A lower P_{IO_2} may cause altitude hypoxemia in critically ill patients. We proposed that if $\%O_2$ is increased during air transport to produce the same $\%O_2$ reading on POAs as measured on the ground, this would produce the P_{IO_2} required to avoid altitude hypoxemia. An MVP-10 ventilator was used to blend O_2 at 40% and 60%. Two Hudson POAs were used and corrected for humidity; POA #1 was calibrated at PB = 748 torr and POA #2 at PB = 700 torr. The $\%O_2$ was blended and analyzed with POA #1 at ground conditions. Then the equipment was placed in an altitude chamber set at PB = 700 torr and readings were taken from POA #1. After pressurization, F_{IO_2} was increased until POA #1 read the same $\%O_2$ as ground conditions. Readings were taken from POA #2 and P_{O_2} was calculated and compared. Mean (SD) data were collected from 10 trials over a 3-day period.

	40% O_2	60% O_2
P_{O_2} at ground (torr)	290	434
POA #1 at PB 700 torr	38%	57%
P_{O_2} at PB 700 torr	270	406
POA #2 after increased O_2 (torr)	43%	64%
P_{O_2} at PB 700 torr after increased O_2 (torr)	291	433

Because the P_{O_2} at 700 torr after the O_2 was increased matched the P_{O_2} at ground conditions, we concluded that this algorithm can be used to compensate for altitude hypoxemia in patients receiving moderate amounts of O_2. O_2 needs beyond that point would reflect changing patient status not altitude. Patients requiring 100% O_2 during ground evaluation are beyond the level of compensation and will require additional ventilatory support during air transport. (OF-91-101)

Evaluation of Closed-System Directional-Tip Suction Catheter—Terry P Hart RRT, C Kees Mahutte MD PhD, VA Medical Center, *Long Beach, California.*

The success rate for left-bronchial-tree suctioning is enhanced by utilizing curved-tip suction catheters. Recently, a directional-tip closed-system catheter became available. PEEP can be maintained and dissemination of secretions minimized with closed-system catheters. We evaluated the efficacy of this catheter in left-bronchial-tree suctioning. **Method**: 75 patients with endotracheal or tracheostomy tubes in place who were scheduled for routine chest x-rays were placed on the Trach-Care Directional Tip (TCDT) closed-tracheal suction system (Ballard Medical Products, Midvale UT). At the time of the chest x-ray an attempt was made to enter the left main bronchus using a standard procedure for catheter introduction. With F_{IO_2} = 1.0 and the head midline, the catheter was advanced with the radiopaque blue line in the 1 o'clock position. The x-ray was evaluated for correct placement of the TCDT catheter. **Results**: Due to pathology and technique, 17% of the x-rays could not be interpreted adequately. In the remainder, overall success rate was 71%. Results were evaluated for possible significance of bevel orientation, tube position in the mouth and trachea, and type of artificial airway. Success rate in tracheostomy tubes alone was 80% (n = 16), in nasal endotracheal tubes 100% (n = 3), and in oral endotracheal tubes 65% (n = 43). Bevel and tube position had no major effect on success rate. **Conclusion:** We find that the Ballard TCDT catheter successfully combines the features of a directional-tip catheter with the advantages of the closed-suction system. (OF-91-087)

Clinical and Laboratory Evaluation of the Impact Uni-Vent 750 Transport Ventilator—Robert S Campbell RRT, Richard D Branson RRT, Kenneth Davis Jr MD, Daniel J Johnson MD, James M Hurst MD, University of Cincinnati Medical Center, *Cincinnati, Ohio.*

Introduction: Maintenance of adequate oxygenation and ventilation during in-hospital transport (T) is essential. We evaluated the Uni-Vent 750 transport ventilator (TV) in the laboratory and during T of 65 ICU patients. **Methods:** In the laboratory, we determined the 750's ability to assure V_T delivery in the face of decreasing C_L of a test lung and evaluated the alarm system (AS). Using a 2-compartment lung model to simulate spontaneous breathing, we evaluated responsiveness of the demand valve (DV) in SIMV and breath triggering in the AMV mode. Clinically, we placed patients requiring T on the 750 at settings identical to those on the ICU ventilator (except F_{IO_2} = 1.0) and compared ABGs and ventilatory variables. **Results:** A reduction in C_L from 0.1 to 0.02 L/cm H_2O caused delivered V_T to decrease slightly as PIP increased. All AS performed to manufacturer's specifications. Triggering of the DV and mandatory breaths occurred at the sensitivity setting with PEEP up to 20 cm. Clinical results are shown in the table. Data was compared using a paired *t* test. Mean (SD) T time was 41 (32) min (range 20-252 min).

	ICU Vent	TV
pH	7.38 (0.04)	7.40 (0.05)
P_{aCO_2} (torr)	39 (8)	36 (6)
P_{aO_2} (torr)	89 (26)	341 (78)*
$\dot{V}_E$ (L/min)	8.6 (2.9)	9.2 (2.5)
PIP (cm H_2O)	46 (12)	50 (17)
PEEP (cm H_2O)	10 (6)	10 (6)
Spontaneous f (breaths/min)	14 (8)	16 (11)

*$p < 0.01$ vs ICU ventilator.

Conclusions: The 750 is a reliable TV capable of providing adequate oxygenation and ventilation in either the SIMV or AMV mode. Care should be taken to assure V_T delivery at high PIP. Triggering is PEEP-compensated, which is unique among TVs. (OF-91-137)

High-Flow Oxygen Delivery Systems: A Comparison of Performance—Robert M Kacmarek PhD RRT, Sara Corcoran RRT, Ray Ritz RRT, Massachusetts General Hospital, *Boston, Massachusetts*; John Curran RRT, Thomas Jefferson Hospital, *Philadelphia, Pennsylvania.* (Work done at Massachusetts General Hospital.)

Precise and consistent oxygen delivery (F_{DO_2}) is frequently required. We compared the performance of 5 high-flow systems: the Misty Ox Gas Injector Nebulizer (GIN), the Downs CPAP Flow Generator (Downs), the Ambu, 2 Ohio nebulizers in parallel (Ohio-2), and 2 high-flow flowmeters (DFM). The Downs, DFM, and Ambu were configured with Cascade I humidifiers. **Methods:** We compared the amount of H_2O delivered, the maximum flow capabilities, F_{DO_2} accuracy, and CPAP compatibility of these systems. Gin, Downs, DFM, and Ohio-2 were set at 40, 60, and 100% oxygen concentrations (O_2) at manufacturer-recommended flow settings or their maximum flow settings if none were specified. Ambu was tested at its 2 settings, 33% and 100%. The effect of 5, 10, and 15 cm H_2O CPAP was evaluated at each F_{DO_2}. Systems were run at each concentration setting for 1 h to evaluate H_2O delivery. Five units of each type were evaluated. **Results:** The DFM and GIN provided precise F_{DO_2} unaffected by any CPAP level. The Ambu set at 33% delivered 32.6 (0.89) % and at 100% delivered 100%. The Downs provided precise F_{DO_2} without CPAP, but the F_{DO_2} increased as CPAP was applied—for example, set F_{DO_2} 0.40, CPAP 10 cm H_2O, actual F_{DO_2} 43.2 (2.2) %; set F_{DO_2} 0.60, CPAP 10 cm H_2O, actual F_{DO_2} 63.8 (0.45) %. Ohio-2 F_{DO_2}s were inaccurate at the 40% (38.6 [0.89] %) and 60% (57 [5.5] %) settings and demonstrated marked increases in F_{DO_2} as CPAP was applied (for example, set F_{DO_2} 0.40, CPAP 10 cm H_2O, actual F_{DO_2} 76.2 [15.7] %; set F_{DO_2} 0.60, CPAP 10 cm H_2O, actual F_{DO_2} 90.6 [6.1] %). The Ohio-2 delivered the most H_2O per hour across all settings (180.4 [34.0] mL), followed by Downs (123 [25.2] mL), GIN [87.4 (13.0) mL], Ambu [69.2 (5.02) mL], and DFM [57.5 (2.3) mL]. **Experience:** The maximum flow through the Ohio-2 was limited (eg, at 0.40 setting 67.4 [12.2] L) while the Downs and DFM whistled at high flows (> 100 L/min). Maximum flow through the Ambu was 101.3 (3.25) L/min. **Conclusion:** Marked variation in performance exists in high-flow systems. Under conditions tested, the GIN, Ambu, and DFM performed precisely and consistently. (OF-91-090)

Volume Monitoring Accuracy of Four Ventilators and the Bicore CP-100 Monitor—Richard D Branson RRT, Robert S Campbell RRT, Prem Srivastava, Kenneth Davis Jr MD, James M Hurst MD, University of Cincinnati Medical Center, *Cincinnati, Ohio.*

We evaluated the V_T monitoring accuracy of 4 adult ICU ventilators (vent) (Puritan-Bennett 7200ae, Hamilton Veolar, PPG IRISA, Siemens Servo 900C) and a proximal airway monitoring system (Bicore CP-100) vs a calibrated pneumotachograph (PT). Two of each vent were used. V_Ts of 0.15, 0.40, 0.80, and 1.2 L were set on the vent and delivered to a test lung. Actual V_T (AV) measured by the PT was compared to V_T measured by the vent and CP-100 under the following conditions: (1) C_L of 0.05, 0.02, and 0.01 L/cm H_2O, F_{IO_2} 0.21, and 0% relative humidity (RH); (2) C_L of 0.05, 0.02, and 0.01 L/cm H_2O, F_{IO_2} 1.0, 0% RH; (3) C_L of 0.05, 0.02, and 0.01 L/cm H_2O, F_{IO_2} 0.21, 100% RH; and (4) C_L of 0.05, 0.02, and 0.01 L/cm H_2O, F_{IO_2} 1.0, and 100% RH. Mean values for 3 consecutive breaths were analyzed. Statistical analysis was performed using a paired *t* test to compare AV to vent and CP-100 measured V_T. **Results:** The table compares V_T measurements using Condition 4. *$p < 0.05$ vs AV. PIP = 14 ± 3, 27 ± 5, 65 ± 6, and 88 ± 9, respectively.

	7200ae			Veolar			900C			IRISA		
Set Vol	AV	Vent	CP-100	AV	Vent	CP-100	AV	Vent	CP-100	AV	Vent	CP-100
0.15 L	0.09	0.14*	0.10	0.08	0.07	0.09	0.08	0.15*	0.08	0.12	0.16	0.12
0.4 L	0.27	0.35*	0.28	0.26	0.26	0.27	0.22	0.36*	0.25	0.29	0.40*	0.30
0.8 L	0.59	0.74*	0.64	0.57	0.56	0.58	0.49	0.72*	0.52	0.58	0.78*	0.54
1.2 L	0.90	1.10*	0.95	0.82	0.79	0.81	0.77	0.99*	0.80	0.89	1.07*	0.84

At normal C_L, vents accurately measure V_T. As C_L falls and PIP rises, vents that measure V_T in the expired limb overestimate delivered V_T due to compressible volume. Additionally, changes in F_{IO_2} and RH % may effect accuracy. The most accurate results were recorded with the Veolar and CP-100. **Conclusion:** Accuracy of V_T measurement varies between vents and with conditions of ventilation. Proximal monitoring of V_T with an independent device may be desirable in some instances. (OF-91-135)

Evaluation of a Transcutaneous CO_2 Device in Monitoring Intentional Hyperventilation in Hemodynamically Stable Head-Injury Patients—Stephen Tunnell BS RRT, David C Willms MD, Margaret Nield PhD, Sharp Memorial Hospital, *San Diego, California.*

The value of noninvasive transcutaneous monitoring of carbon dioxide levels (P_{tcCO_2}) has been demonstrated in neonates and adults with sleep disorders. Such technology should be applicable in adult intensive care settings. The purpose of this study was to establish the level of agreement between P_{tcCO_2} and P_{aCO_2} in hemodynamically stable, adult head-injury patients receiving intentional hyperventilation for control of intracranial hypertension. The convenience sample consisted of 64 corresponding sets of P_{tcCO_2} and P_{aCO_2} measurements from 6 adults (4 men, 2 women, 19-49 y). The P_{tcCO_2} was monitored using the FasTrac Respiratory Status Monitor (SensorMedics Corp, Anaheim CA). The P_{aCO_2} was measured with 1306 Blood Gas Analyzer (Instrumentation Laboratory, Lexington MA). Both devices were calibrated according to the manufacturers'

recommended procedure. The mean (SD) P_{tcCO_2} was 27.1 (5.1) and the mean (SD) P_{aCO_2} was 28.4 (4.7). Data were analyzed utilizing the Bland and Altman statistical method for assessing agreement between 2 methods of clinical measurement, Lancet 1986. The differences between the datapoints were plotted against their average. The strength of agreement was summarized by bias (mean P_{aCO_2}-P_{tcCO_2} difference) 1.34, standard deviation of the differences 2.28, and upper and lower limits of agreement, which were -3.22 and 5.9, respectively. Although the correlation coefficient indicated a strong relationship ($r = 0.9$, $p < 0.001$), the Bland and Altman technique showed that 95% of the population fell within the limits of agreement (which were large enough to be clinically important) and indicated a tendency for poor agreement between the 2 devices. These findings suggest P_{tcCO_2} measurements should not replace P_{aCO_2} monitoring in intentionally hyperventilated patients. (OF-91-006)

The Influence of Endotracheal Tube (ETT) and Test Lung Compliance (C_{TL}) on Downstream Pressure during High-Frequency Oscillatory Ventilation—Frank Monaco BA RRT, Keith S Meredith MD, Scott Hassell BS. Memorial Hospital, *Colorado Springs, Colorado.*

Introduction: Multiple factors may influence the magnitude of transmitted pressure during high-frequency oscillatory ventilation (HFOV). Using a bench test we sought to determine (1) the impact of ETT size on peak-trough pressure (ΔP) and (2) the impact of changing C_{TL} on ΔP. **Methods**: The HFOV (3100 SensorMedics, Anaheim CA) was connected via 2.5- and 3.5-mm ETTs to a test lung (TTL, Michigan Instruments, Grand Rapids MI). Pressure was measured by calibrated transducers (DP45, Validyne, Northridge CA) with a frequency response flat ±10% to 1000 Hz and range = ±100 cm H_2O, placed proximally (ΔPp) and distally (ΔPd) to the ETT. Constant HFOV parameters were P_{aw} = 10 cm H_2O, f = 15 Hz, and I-E ratio = 1:2. The ventilator ΔP was varied from 10 to 70 cm H_2O in 10- cm H_2O increments, and the C_{TL} was changed from 1.0, 2.0, and 3.0 mL/cm H_2O at each ventilator ΔP. **Results**: There were 7 measurements of ΔPp and ΔPd at each C_{TL} for each ETT (n = 84). The table represents pooled data as the mean (SD). Data were analyzed by repeated-measures ANOVA. Changing ETT size impacted transmitted pressure ($p < 0.001$), but changes in C_{TL} did not ($p = 0.974$).

Compliance	ΔPp (n = 14)	ΔPd (n = 14)	ETT	ΔPp (n = 21)	ΔPd (n = 21)
1	17.6 (9.4)	9.5 (5.2)	2.5 mm	17.8 (9.3)	7.6 (4.1)
2	17.7 (9.4)	9.6 (5.4)	3.5 mm	17.6 (9.5)	11.8 (5.6)
3	17.8 (9.5)	10.0 (5.5)			

Conclusions: During HFOV with this device and at the settings described (1) distal pressure measurements did not reflect changing C_{TL} and (2) changing ETT size did change transmitted pressure. Therefore anything varying airway lumen (eg, changing ETT, mucus accumulation, or a kinked ETT) will alter delivered pressures and, therefore, volumes. (OF-91-046)

A Critical Look at Some Everyday Clinical Events

Detrimental Effect of Ambient Temperature on the Humidity Output of Fisher-Paykel MR-630 Heated Humidifier with the MR-390 Autofeed Chamber—Stephen J Connell BA RRT, Shawn Weckerly CBET. Thomas Jefferson University Hospital. *Philadelphia, Pennsylvania.*

During quality assurance monitoring of ventilated patients, we noted lack of humidity mist in some MR-390 chambers at $\dot{V}_E$ below 12 L/min. Operating instructions provided by Fisher-Paykel indicated maximum flowrate as 50 L/min. **Hypothesis:** Ambient room temperatures (AT) above 24°C are a significant variable in relative humidity (RH) output of the system. **Method & Materials**: We measured RH of gas run through a simulated breathing system with a factory-calibrated, NBS traceable hygrometer-thermometer (Fisher Scientific, 11-661-7A) attached to the end of the inspiratory limb of a heated-wire adult ventilator circuit (Isothermal). We simulated a range of ATs by placing a MR-630 and circuit inside a double-wall isolette (Narco Scientific, Airshields Division) and adjusting temperature setting in 2° increments from 24-34°C. We arranged the tubing so that patient-Y and temperature probe protruded 50 mL beyond the isolette via an access port to eliminate ambient heating of the probe as a variable. Each heater was set at 34°C. RH setting was 0 to eliminate wire-drying of gas. Continuous gas flow of 25 L/min was measured with a Timeter RT-200 flow calibrator and constantly maintained for all trials. Internal isolette temperature and RH were recorded 20 min after each temperature adjustment. The experiment was run 4 times using different sets of MR-630 humidifiers, MR-390 chambers, and tubing circuits. **Results**: The mean (SD) results were

AT (°C)	24	26	28	30	32	34
	(0.16)	(0.2)	(0.16)	(0.16)	(0.11)	(0.1)
RH (%)	78.4	73.2	60.8	51.3	40.3	32.8
	(16.7)	(19)	(18.9)*	(15.9)*	(12.4)*	(11.2)*

* $p < 0.05$ by Student's t test. $r = -0.992$, $p < 0.001$ between AT and RH. Laboratory temperature constant 20°C; patient-Y temperature constant 34°C.

Discussion: Current literature recommends that inspired gases for intubated patients should be 100% humidified at 32-34°C. These trials confirmed a decrease in RH as AT increased, making the MR-390 clinically unreliable. Product testing of heated humidifiers is done at AT ranges of 20-24°C. **Conclusion:** Because ICU rooms may exceed these temperatures, especially in the presence of airbeds and heat-generating equipment, future evaluation of humidity output should include these higher temperature ranges. (OF-91-016)

The Effect of Oral Breathing on O_2 Concentrations Delivered by Nasal Cannula—Crystal L Dunlevy EdD RRT, Sylvia E Tyl BS CRTT, The Ohio State University; Jeffrey Weiland MD, The Ohio State University Hospitals—*Columbus, Ohio.*

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The major respiratory care textbooks differ in their discussions of the cannula's therapeutic range and its limitations. A review of the literature revealed few studies that examined the effect of oral versus nasal breathing on delivered O_2 concentrations. These studies have serious limitations and report conflicting results. Our study attempted to determine whether a difference in delivered O_2 concentration exists between mouth-open and mouth-closed breathing. Fifteen healthy subjects over the age of 20 with no history of smoking, pulmonary, or cardiac disease participated in the study. The naso- and hypopharynx of each subject were anesthetized with 10% xylocaine. A 6.5-Fr suction catheter was inserted through the nose into the hypopharynx under direct vision and secured. Subjects were placed on a nasal cannula at 2 L/min and instructed to vary their breathing pattern, alternating among mouth-open normal ventilation, mouth-open hyperventilation, mouth-closed normal ventilation, and mouth-closed hyperventilation. The order of breathing patterns was randomly assigned. Subjects breathed through a mouthpiece, with either 1 or 2 one-way valves in place to allow for mouth-open or mouth-closed breathing. Respiratory rate was monitored and controlled by having subjects breathe with a metronome at a rate of 14 or 24 breaths/min. Subjects maintained their normal V_T (400-700 mL) throughout the study, verified with a Wright's respirometer, using a calibrated Nellcor end-tidal CO_2 monitor to verify normal and hyperventilation. After subjects maintained a breathing pattern for 5 min, hypopharyngeal gas samples were aspirated using a glass syringe with a three-way stopcock. Gas samples were analyzed for P_{O_2} by a calibrated Corning 165 blood gas machine, and F_{IO_2} values were calculated as follows: F_{IO_2} = P_{O_2} of gas/measured barometric pressure − 47. Mean (SD) were calculated for each set of F_{IO_2} and P_{etCO_2} values. Two-tailed, paired *t* tests were applied, with $p < 0.01$ considered to be statistically significant. The mean (SD) F_{IO_2} values for mouth-open breathing were 0.24 (0.03) and 0.23 (0.03) for normal and hyperventilation, respectively; mean F_{IO_2} values for mouth-closed breathing were 0.31 (0.06) and 0.27 (0.03) for normal and hyperventilation, respectively. Analysis revealed that F_{IO_2} values during mouth-closed breathing were 0.78 higher ($t = 6.24$; $p \leq 0.00001$) than during mouth-open breathing during normal ventilation; and 0.42 higher ($t = 5.28$; $p \leq 0.0001$) during hyperventilation. F_{IO_2} values of samples obtained during normal ventilation with mouth-closed were 0.4 higher than during hyperventilation, mouth-closed ($t = 3.96$; $p \leq 0.001$). There was no statistical difference in oxygen concentration with mouth-open breathing, normal versus hyperventilation ($t = 1.47$; $p = 0.16$). These findings may help to establish guidelines for nasal cannula use, ultimately improving patient care by decreasing the incidence of ineffective treatment. (OF-91-127)

What Factors Influence Noise Levels Inside Oxygen Hoods?—Jackie Smith BS CRTT, Paul J Mathews EdS RRT. University of Kansas Medical Center, *Kansas City, Kansas.*

Introduction: We conducted a bench study of the effects on noise level in commonly used neonatal environmental chambers when humidifier type, F_{IO_2} setting, water level, and chamber type were varied. The American Academy of Pediatrics (AAP) recommends that sound levels be kept below 58 dBa (decibels above reference noise) in incubators and NICUs. **Methods:** 4 types of oxygen chambers (large, small, oblong, and hut types) were tested for sound levels under 3 water-level conditions (full, half full, and empty), with 2 humdification systems (Conchapak and Aquapak all-purpose nebulizer), and at 6 F_{IO_2} settings (0.98, 0.80, 0.60, 0.40, 0.35, and 0.28) at a constant (7 L/min) flow. A Realistic Sound Level Meter (#33-2050) employing an A-weighted scale to filter out low-frequency noise was used to measure sound levels; background noise was kept constant. 144 observations were made and data recorded. Descriptive statistics were calculated and the data subjected to ANOVA for repeated measures and the Newman-Keuls Multiple Comparison Tests. **Results:** All observations exceeded 62 dBa, 89 observations exceeded 80 dBa. The ANOVA indicated statistically significant differences based on water level and type of chamber ($F = 3.89$, $p \leq 0.01$). The multiple comparison tests also showed significant differences based on water level ($F = 5.667$-1.604, $p = 0.01$, $df = 120$), chamber type ($F = 1.833$, $p = 0.01$, $df = 120$), and nebulizer type ($F = 8.625$, $p = 0.01$, $df = 120$). Noisiest combination was hut with full all-purpose nebulizer; Aquapak all-purpose nebulizer had highest mean sound level (MSL) under all conditions with all chambers; hut with full Conchapak had lowest MSL with full humidifier; MSL continued to fall with decreasing water levels in Conchapak. **Conclusion:** Although oxygen chambers are inherently noisy, significant reduction in noise levels can be realized through careful choice of chamber and humdification equipment. We conclude that, although all combinations exceeded AAP recommendations, there is a 'best' combination of chamber, nebulizer type, and water level to reduce noise. (OF-91-053)

What Are the Top 10 Sources of Annoying Noise in the ICU and How Loud Are They?—Paul J Mathews EdS RRT, Albert Long BS RRT, Greg Baker BS RRT. University of Kansas Medical Center, *Kansas City, Kansas.*

Introduction: An ICU is a place of persistent and invasive noise. Noise produces stress and prevents rest. In order to determine the sources and volumes of noise in the ICU, a survey of 100 patients was conducted and the 10 noise sources most often identified as "annoying" were analyzed for sound level. **Method:** 100 sequential qualifying patients who were transferred from an ICU were surveyed. Patients included 59 men and 41 women, ranging from 37 to 76 y. All subjects were lucid, oriented, and denied any appreciable hearing loss. The questionnaire included 5 items related to the type of ICU the patient had been in, type of room occupied, and equipment used. The subjects were asked to rate the sound level in the ICU on a 4-point Likert-type scale, and to identify the 5 sounds most annoying to them. The top 10 sounds were then determined by ranking and tallying responses. A Realistic Sound Level Meter (#32-2050) was used with an A-weighted, slow response scale to determine the sound levels emitted by

the 10 sources. **Results:** Our survey of patients indicated the 10 most annoying sounds include those produced by suction equipment (most annoying) and by 4 types of alarm systems (including ventilators, pulse oximeters, cardiac monitors, and I.V. pumps). Measurement of the sound levels of the identified equipment ranged from 52 to 110 dBa (decibels above reference noise). The OSHA-recommended maximum sound level (dBa slow response) is less than 90 dBa for greater than 8 h/d duration. **Conclusion:** Many of the "annoying" noises in the ICU are controllable by health-care professionals. Many of these sounds exceed recommended occupational levels and may result in adverse conditions for both patients and staff. (OF-91-054)

Carpal Tunnel Syndrome as a Manifestation of Cumulative Trauma Disorders in RCPs—Richard M Ford BS RCP RRT, Kim M Goodreau RCP RRT, David M Burns MD. UC San Diego Medical Center, *San Diego, California.*

Carpal tunnel syndrome (CTS) is a common manifestation of a cumulative trauma disorder in a number of occupations where extensive use of the hands is part of the routine task, but has not been previously reported as an occupational hazard for RCPs. We have noted an unusually high frequency of CTS among our RCP staff; 6 out of a total staff of 45 RCPs have developed symptoms consistent with this diagnosis and 3 required surgery. The frequency of this diagnosis is much higher among those members of the staff who routinely perform chest physiotherapy (CPT) as a major portion of their work load (5/15), in comparison with those who predominantly manage ventilator care (1/30). **Case Summaries**: A 47-year-old woman working as a RCP since 1982 without previous medical history of hand/wrist injuries developed symptoms of pain, swelling, stiffness in the anterior portion of the thumb and wrist. The pain was persistent, worsened with use of a mechanical vibrator to perform CPT, and was relieved by avoiding performance of CPT. A 43-year-old woman working as a RCP since 1989 recently experienced moderate pain and mild swelling in the posterior region of the right wrist. The pain was experienced after a normal days' work and, more specifically, after performing CPT. When she was away for several days, her wrist was almost pain-free. A 48-year-old man who has been working as a RCP since 1981 noticed a mild discomfort during and after performing CPT with the G-5 vibrator. The pain and related symptoms progressed to a moderate/severe level. His symptoms decreased significantly when he was away from his job. **Conclusion**: CTS may be an occupational hazard associated with repetitive performance of CPT. We have made the following changes to minimize the transfer of vibration to the hand/wrist area of the RCP: modifications in percussor handles, gloves for RCPs performing CPT, different models of percussors, education programs on ergonomics and body mechanics, introduction of other secretion clearance techniques, and incorporation of a system to monitor appropriate utilization of therapy. The impact of these changes in reducing the number of hand/wrist disorders will be further assessed. (OF-91-032)

Collaborative Care Councils: An Approach to Team Building—James E Burchfield BS RCP RRT, University of Texas Medical Branch, *Galveston, Texas*; Carol H Johnson MS RN, Linda K Ross BA RRT, Douglas G Sabau RRT, Richard Pozda BS RN, St Luke's Episcopal Hospital—*Houston, Texas.*

An evaluation of a program for team building in a 41-bed cardiovascular recovery unit (CVRU) was performed. A review of quality assurance issues indicated a high incidence of conflict between nurses (RNs) and respiratory therapists (RTs). A Collaborative Care Council (CCC) comprised of 3 RTs and 3 RNs met bi-monthly to identify issues to be resolved. Pre- and post-surveys were developed to quantify perceptions of conflict between the 2 professional groups. The surveys focused on (1) role delineation, (2) communication, and (3) working relationships. Surveys were completed by 76 individuals; 53 RNs and 23 RTs. Results indicated that 23.58% of RNs did not understand role delineations compared to 6.6% of RTs; 45.28% of RNs and 31.8% of RTs felt that communication was inadequate between the 2 groups; and 26.42% of RNs and 22.73% of RTs felt a negative working relationship existed. The CCC developed and implemented programs to address identified issues. Specific programs instituted included (1) RN/RT orientation, (2) formation of a team communication board, (3) conflict resolution workshop, (4) RT/RN in-services, (5) RT/RN standardization of policies and procedures, and (6) creation of RT CV Specialist positions. A second survey was performed to quantify changes in perception following program implementation; 70 surveys were returned (58 RNs and 12 RTs). RNs identified no improvement in the area of role delineation (52.50% favorable response). Improvement in communication and working relationships was noted by RNs (70% and 90%, respectively). RTs expressed a 100% favorable response in all areas. Subsequent QA analysis revealed no evidence of RN/RT conflict. In summary, improvement in communication leads to better working relationships, which are essential to conflict resolution. We recommend the use of Collaborative Care Councils to build a team approach to patient care. (OF-91-025)

Chest Physical Therapy in Pediatrics: A National Survey—Robert Lewis RRT. The Children's Memorial Hospital, *Chicago, Illinois.*

Chest physical therapy (CPT) is a widely used procedure in pediatrics. I conducted a survey to gather information on utilization patterns. **Methods:** 56 childrens hospitals (CHs) and 50 general hospitals (GHs) with large pediatric departments were surveyed to quantify CPT utilization patterns. All CHs responding were included in the results, but only GHs with more than 100 beds were included. **Results:** 34 (61%) of CHs responded, 10 did not do CPT, or had incomplete data. Only 5/14 GH respondents were > 100 pediatric beds and had complete data available. Results are mean (SD). The number of treatments (txs) was 194 (182) txs/bed/y (range 15-877); the median number was 136 txs/bed/y. 70% of hospitals had less than 200 txs/bed/y. The total number of hours devoted to CPT

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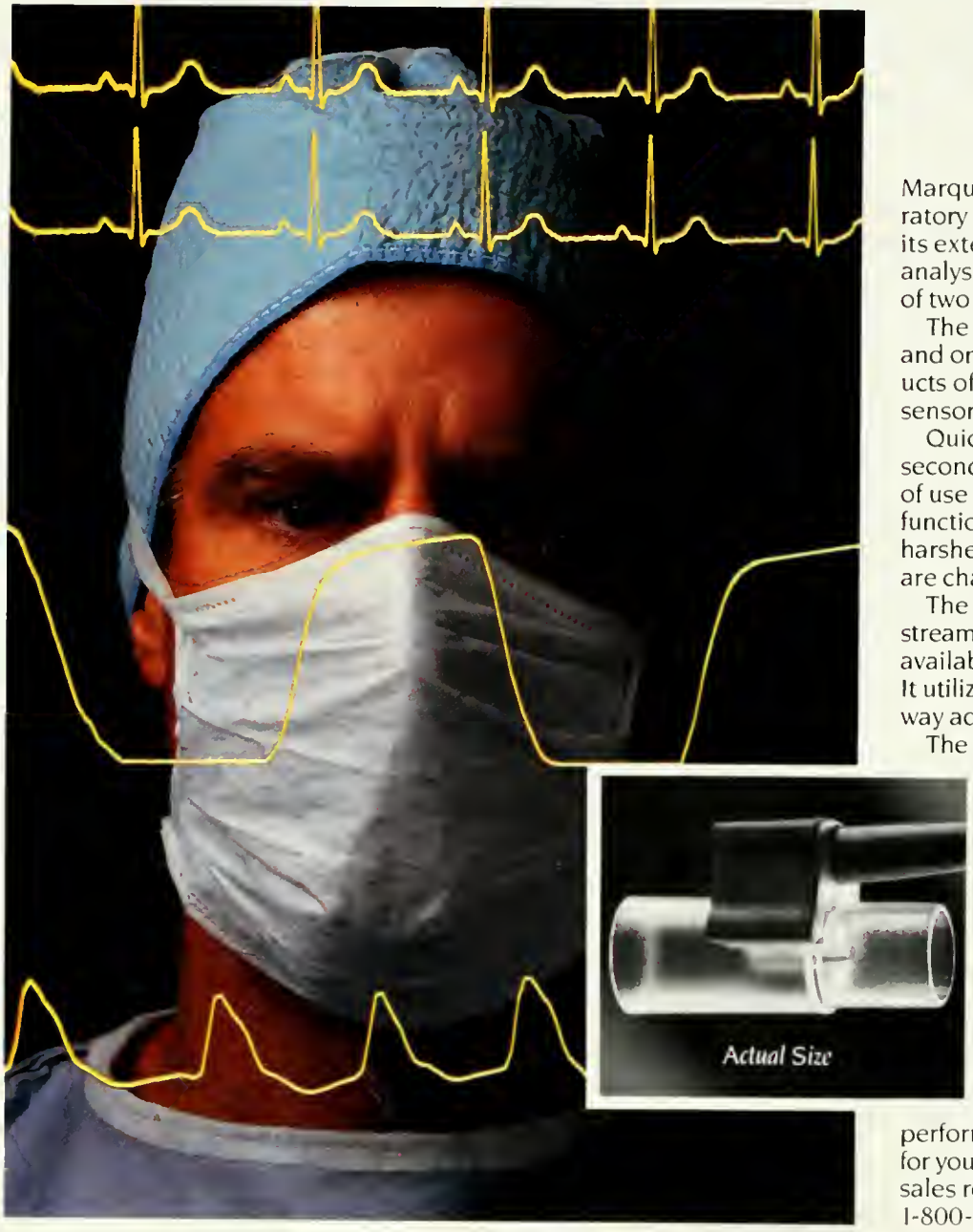

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also varied considerably, 49 (38) h/bed/y, and median 39 (range 7-146). 70% of hospitals devoted fewer than 50 h/bed/y to CPT. Mean (SD) tx time (for non-CF) was 17 (10) min (range 5-42). A weak but significant correlation existed between bed size and tx/y ($r = 0.44$, $p < 0.05$). 58% had an automatic stop policy, most commonly 72 h (range 24-120 h). Hospitals with automatic stop orders had significantly fewer txs/bed/y (132) than those with no policy (261) ($p < 0.05$, Wilcoxon rank sum test). Listed as common indications for CPT (besides CF) were pneumonia by 77% of respondents, atelectasis 71%, recent extubation in newborns 46%, bronchiolitis 34%, and asthma 11%. **Conclusions:** CPT utilization varies widely. The data presented are skewed due to a few CHs with very high utilization rates; therefore, median values may more accurately describe utilization patterns. Automatic stop policies significantly reduce CPT utilization. CPT is also widely used in conditions for which a scientific basis for its application is lacking (eg, pneumonia, bronchiolitis). (OF-91-111)

Monitoring the Sick Infant and Child

An In-Vitro Comparison of 3 Methods of Compliance Measurements—Frank Monaco BA RRT, Keith S Meredith MD. Memorial Hospital, *Colorado Springs, Colorado.*

Introduction: Various methods of determining compliance (C_L) at the bedside are available to the clinician that differ in method of calculation and thus may differ in yielded values. We compared 3 methods of C_L measurement using a test lung (TL) (TTL, Michigan Instruments, Grand Rapids MI). **Methods**: TL compliance (TL actual) was validated by injecting 100 mL from a calibrated syringe and measuring static airway pressure (P_{aw}). The TL was mechanically ventilated (Sechrist IV 100) with PIP/PEEP = 25/2 cm H_2O and each method tested in sequence; the TL compliance was then varied and the process repeated. Compliance 1 (C1) was calculated by V_{Ti} (mL)/(PIP-PEEP) (cm H_2O). (NVM-1, Bear Medical, was used for V_T measurement, and Pneumogard, Novametrix Medical, used for measurement of PIP/PEEP.) Compliance 2 (C2) was obtained from pressure-volume curves, ie, V_{Ti}/PIP (maximum P_{aw} during inspiration) – PEEP (last P_{aw} before inspiration); Compliance 3 (C3) was measured by single-breath occlusion (total extrapolated passive expiratory volume/P_{aw} during end-inspiratory occlusion). (Measurements for C2 and C3 obtained with 2600, SensorMedics Corp.) **Results**: All data are presented as the mean (SD). Data were pooled by method and analyzed by ANOVA. There were no significant differences ($p = 0.185$) between the TL actual and C1, C2, or C3. However, the arithmetic difference between TL actual and each C_L method was significantly different ($p < 0.05$).

	Compliance in mL/cm H_2O (n = 4)		
TL actual	C1	C2	C3
1.01 (0.01)	0.82 (0.01)	0.91 (0.04)	0.90 (0.01)
1.93 (0.01)	1.42 (0.01)	1.64 (0.01)	2.01 (0.04)
2.87 (0.01)	1.93 (0.01)	2.35 (0.03)	2.84 (0.04)

Conclusion: Each method of C_L measurement showed a high degree of reproducibility and followed changes in TL actual. However, C3 (static method) varied less from TL actual than C1 and C2 (PIP methods). These data suggest each method may be used to clinically trend changes in C_L; however, precise C_L measurements require static airway pressure methodology. (OF-91-007)

Accuracy of Space Lab and Nellcor's Pulse Oximeters in Infants and Children with Congenital Heart Disease—Mary Dekeon RRT, Jon Meliones MD, Shelley Clifton RRT. University of Michigan Medical Center, Ann Arbor, Michigan.

Frequently, infants and children with congenital heart disease have decreased arterial oxygen saturations (S_{aO_2}) due to intracardiac shunting. While pulse oximetry (S_{pO_2}) has become a standard monitoring tool in hospitals, no current data support the correlation of the monitors with measured S_{aO_2} in this patient population. **Method:** We evaluated the correlation of S_{pO_2} via two pulse oximeters—the Nellcor N-200 (Nell) and the Space Lab 90489 (SL)—with S_{aO_2} in patients with congenital heart disease. We were primarily interested in the correlation in patients whose S_{aO_2}s were < 95%; we hypothesized that S_{pO_2} may have poor correlation in infants and children with S_{aO_2}s < than 95%. 49 patients have thus far been entered into the study. In each patient (age range 1 day to 25 y), a Nellcor and a Space Lab monitor were placed on the same extremity as the arterial line. Stabilization with both monitors was achieved for 10 to 15 min. Both monitors were required to demonstrate correspondence with the patient's electrocardiogram and arterial waveform. After documentation of heart rate correlation, an arterial blood gas was drawn and analyzed on an Instrumentation Laboratory (IL) 1312 blood gas analyzer and IL 482 CO-oximeter for a measured saturation. 49 samples were obtained, 39 of which had a measured saturation < 95%. **Results:** Mean (SD) saturations obtained in the 49 samples were Nell 84 (2) %, SL 90 (11) %, and S_{aO_2} 86 (11) %.

All Samples (n = 49)	r^2	Sats < 95% (n = 39)	r^2
Measured = $0.75X^{Nell} + 22$	0.66	Measured = $0.62X^{Nell} + 32$	0.50
Measured = $1.1X^{SL} - 13$	0.79	Measured = $0.96X^{SL} - 1$	0.75

In both groups, SL monitor demonstrated a higher correlation, slope closer to 1, and lower intercept than the Nell. Nell correlation, slope, and intercept became more disparate in the group of patients with $S_{aO_2} < 95\%$. It appears that the Space Lab monitor may provide more accurate representation of S_{aO_2} in patients with congenital heart disease. (OF-91-148)

Endotracheal Tubes in Two Neonates Abutt the Tracheal Wall Causing Inadequate Ventilation—John A Lund BA RRT, Jon L Swegarden BS RRT, Children's Hospital-MeritCare; Craig T Shoemaker MD, CJ Menagh MD, Fargo Clinic-St Lukes Hospitals—*Fargo, North Dakota.*

It is common in intensive care nurseries for mechanically ventilated infants to have spells characterized by rapid deteriora-

tion of vital signs and diminished or absent breath sounds. These spells are usually interpreted as breath-holding events, bronchospasm, or a plugged endotracheal tube (ETT). A 25-wk gestational age (GA) boy, birthweight (BW) 964 g, 8-days old at time of study, intubated with a Portex 3.0 ETT, and a 24-wk GA girl, BW 600 g, 36-days old, intubated with a Portex 3.0 ETT, were having intermittent spells. Both were on Sechrist IV 100B ventilators. Lung mechanics measurements were performed with the SensorMedics 2600 Pediatric Pulmonary Cart to determine the true identity of these spells. In preparation for the study, positioning resulted in deterioration of vital signs, diminished breath sounds, and lack of chest movement. Data collected at this time revealed a normal pressure waveform but no flow or volume delivered to the patient. The ETT was felt to be malpositioned or plugged; the infants were repositioned and manually ventilated. Vital signs returned to normal. Lung mechanics measurements showed normal inspiratory and expiratory flows. Anterior-posterior chest radiographs revealed the beveled end of the ETT facing the left wall of the trachea. Lung mechanics were repeated with the infants' heads in a variety of positions. Inspiratory and expiratory flow decreased and eventually stopped in both infants with the neck flexed and the head to the right. **Conclusion:** Each patient had a large ETT and deteriorated with neck flexion and head facing opposite side of the ETT orifice. We hypothesize that the ETT orifice was abutting the tracheal wall, not allowing for ventilation, although the pressure-limited, time-cycled ventilator continued to function properly. More study needs to be done to determine standards for direction of ETT orifice after intubation and the positioning of neck and head in intubated neonates. (OF-91-151)

A Simplified Method for Assessing Ventilatory Drive in Infants—Alberto Rubio RPFT RRT, Patricia Walters RPFT RRT. Children's Medical Center, *Dallas, Texas.*

We evaluated a system comprised of a Perkins-Elmer Mass Spectrometer Model 1100, a SensorMedics 2600 Infant PFT system, and a simple rebreathing circuit for assessing ventilatory drive in infants via hypercapnic challenge as defined by Read. Using a ventilator circuit appropriate for a 7-kg child, we constructed a rebreathing circuit with a Hans Rudolph two-way nonrebreathing valve (NRV) model 2210B. A Hans Rudolph 2430 series automatic controller with a two-way balloon valve (TWBV) and latex bag served as a gas reservoir with the TWBV attached by its side port to the inspiratory side of the NRV. A large-bore ETT adapter was secured at the pigtail. Tubing attached at the exhalation side of the NRV connected with the adapter, completing the circuit. A port drilled into the NRV was source for the mass spectrometer's 1 mL/s capillary sampling line. The mass spectrometer was calibrated to measure high and low O_2 and CO_2 in torr. Using the controller, test gas flowed through one end of the TWBV, filling the latex bag attached at the other end with a volume equal to 3 times the patient's VC. The 2600's pneumotach connected to the NRV and interfaced with the sedated patient via face mask. The flow-volume test screen provided the V_T and f needed to calculate $\dot{V}_E$ while the mass spectrometer provided P_{etCO_2}. Serial measurements were hand written. Normal CO_2 responses have been published only for adults. Unlike Read, we found it helpful to divide $\dot{V}_E$ by body surface area to normalize data when such was < 1 m^2. Captured data on 3 patients were stable, reproducible (slopes were similar but r was variable), and interpreted as reliable. We further validated system and technique by twice testing an adult who had been CO_2 challenged and tested via SensorMedics MMN Horizon 4400. Results with our system were comparable to one another and to 4400 results. This method was successful, obviated the need for a multi-channel recorder, and utilized equipment present in or accessible to most laboratories. We have replaced the steady-state method with this technique because it is faster, less irritating to the patient, and offers cost savings in technician time and number of tests needed, thus halving cost to patient. (OF-91-164)

Another Predictor of Mortality in Infants with Congenital Diaphragmatic Hernia—Lynne K Bower RRT, Jay M Wilson MD. Children's Hospital, *Boston, Massachusetts.*

Despite recent advances in neonatal life support and technology such as extracorporeal membrane oxygenation (ECMO), many infants with congenital diaphragmatic hernias (CDH) die. Previously published data from our institution indicate that survival can be predicted based on the best post-ductal P_{aO_2} ($BPDPO_2$) achieved on maximum mechanical ventilation prior to ECMO. From these data, CDH patients are classified as responders (R, $BPDPO_2$ > 100 torr) or non-responders (NR, $BPDPO_2$ < 100 torr). R who require ECMO have a survival rate of 65% vs 9% for NR. Both R and NR infants have been successfully weaned from ECMO only to expire at a later date. The purpose of this study was to focus on CDH patients who were weaned from ECMO to see if additional predictors of outcome could be identified. **Method.** We reviewed the charts of all CDH infants who required ECMO from 1987-1991 (n = 55). Ventilator management for all patients was identical during and while weaning from ECMO. Our criteria for weaning from ECMO are normal P_{aCO_2} and P_{aO_2} > 60 torr on ventilator settings of 30% O_2, f 30, and PIP/PEEP of 30/5 cm H_2O. Patients were classified as either R or NR. ABGs from the last successful trial off ECMO prior to decannulation were collected. **Results**: Of the patients who successfully weaned from ECMO (n = 30), 27% (6/22) of R and 75% (6/8) of the NR died. We noted a statistically significant difference in outcome based on the P_{aCO_2}. When the P_{aCO_2} was below 36 torr, 82% (14/17) survived. When the P_{aCO_2} was > 35 torr, 23% (3/13) survived ($p < 0.05$ by ANOVA). NR with P_{aCO_2} > 36 torr had a 100% mortality rate (7/7). **Conclusions**: We conclude that incorporating the pre-decannulation P_{aCO_2} with the pre-ECMO $BPDPO_2$ will further improve our ability to predict outcome. Knowing the mortality post-ECMO may prompt us to intervene with new modes of ventilation. Additionally, perhaps CDH infants with a P_{aCO_2} > 35 torr could benefit from additional time on ECMO despite meeting other criteria for decannulation. (OF-91-021)

Optimizing Lung Mechanics with the Use of Flow-Volume (F-V) Loops in a Pediatric Patient—Valerie K Preston CRTT, John A Lund BA RRT, Children's Hospital-MeritCare; Gerald F Atwood MD, Fargo Clinic-Children's Hospital-MeritCare—*Fargo, North Dakota.*

We present a 2 1/2-year-old boy with pulmonary hypoplasia and marked hypotonia and a tracheostomy who has been ventilator-dependent since birth. The patient was weaned to pressure support of 8 cm H_2O, PEEP 4 cm H_2O, F_{IO_2} 0.21 on a Siemens Servo 900C. Periodic CPAP trials were poorly tolerated, and the patient could not be weaned further. F-V loops were obtained to determine the level of CPAP needed to optimize lung mechanics. Data were collected while the patient slept, using a calibrated SensorMedics 2600 pediatric pulmonary cart. The study was done with the patient on a Cardens CPAP device with 0, 3, 6, and 8 cm H_2O of support.

	CPAP 0	CPAP 3	CPAP 6	CPAP 8
Inspiratory time (t_i, in s)	0.53	0.54	0.45	0.53
Expiratory time (t_e, in s)	2.89	2.79	0.55	0.52
Peak tidal expiratory flow (PTEF, in mL/s)	136	136	168	192
Mid-tidal expiratory flow/mid-tidal inspiratory flow (ME/MI)	0.14	0.17	0.69	0.96

Tracheomalacia is evidenced by incomplete structural support of the trachea, in which the normal luminal narrowing during expiration becomes exaggerated causing decreased expiratory flows. An indicator for diagnosing tracheomalacia is the ratio ME/MI. An ME/MI of approximately 1.0 is considered normal and a value < 0.65 indicates decreased expiratory flow caused by an intrathoracic upper-airway obstruction. In this patient, increased levels of CPAP "stented" the airway open allowing PTEF to increase and ME/MI to normalize. The patient was subsequently placed on CPAP of 8 cm H_2O, which he tolerated well. Over the next 6 mo, as airway function improved, CPAP was decreased to 2 cm H_2O and tolerated for approximately 18 hours per day. This case suggests that there is a role for lung mechanics measurements in the diagnosis of tracheomalacia. F-V loops may be used to optimize airway mechanics and determine the best treatment. (OF-91-071)

Chlorpromazine Therapy in a Neonate with Persistent Pulmonary Hypertension Complicated by Pulmonary Hemorrhage—Lisa L Ellison RRT, Robert H Warren MD. Arkansas Children's Hospital, *Little Rock, Arkansas.*

Tolazoline is a pulmonary vasodilator frequently used in the treatment of persistent pulmonary hypertension of the newborn (PPHN). Side effects include hypotension and pulmonary hemorrhage (PLH), precluding its use in this patient population. We report on the use of chlorpromazine (CPZ) for direct relaxant effect on vascular smooth muscle with limited side effects. **Case Summary:** A 38-week gestational age, 3.3-kg infant was referred for severe hypoxemia and respiratory distress. Prior to transport he was intubated and ventilated with F_{IO_2} 1.0, f 60, PIP 23 cm H_2O, PEEP 2 cm H_2O. P_{aO_2} was 26 torr, and severe PLH developed. On arrival, echocardiography revealed normal cardiac anatomy with a large patent ductus arteriosus and right-to-left shunt. ABG revealed pH 7.39, P_{aCO_2} 37 torr, P_{aO_2} 41 torr, and HCO_3^- 22 on f 70, PIP 25 cm H_2O, PEEP 3 cm H_2O, and F_{IO_2} 1.0. Due to PLH, the infant was not a candidate for ECMO or tolazoline, but was treated with blood products and 7-cm H_2O PEEP. Hyperventilation, tromethamine, dopamine, dobutamine, sedatives, and vecuronium were used to treat PPHN. Severe hypoxemia continued despite maximal medical management. On Day 3 P_{aO_2} remained in the 20-40 torr range; 0.8 mg of CPZ was given I.V. over 1 h, resulting in an initial increase in P_{aO_2} to 394 torr on f 150, PIP 30 cm H_2O, PEEP 6 cm H_2O, and F_{IO_2} 1.0. After 2 doses of CPZ, the infant was weaned to f 45, PIP 22 cm H_2O, PEEP 5 cm H_2O, and F_{IO_2} 0.98 while maintaining P_{aO_2} > 50 torr. $\bar{P}_{aw}$ decreased from 16 to 9. The infant received 0.4 mg CPZ q4h and was weaned from CPZ after 3 days. No serious complications attributable to CPZ were observed. Vasopressors were decreased during CPZ administration. The F_{IO_2} was decreased slowly, first by 1% and then by 2% increments. He was extubated and placed on a 30% hood after 6 days of mechanical ventilation. Hemodynamic data were not measured. Repeat echocardiography revealed no shunt after treatment with CPZ. **Conclusion:** Patients with PPHN complicated by PLH have a > 80% mortality rate. Our limited experience suggests that CPZ is a safe and effective therapy, with its value demonstrated by the improvement in oxygenation as well as the limited side effects observed. The use of CPZ in this type of patient warrants further evaluation using prospective studies. (OF-91-009)

Effect of Flowrate on CO_2 Levels in an Infant Oxygen Hood (O_2H)—Wesley Brown RCP CRTT, Randy Scott BS RCP RRT, Gerald Nystrom MD. Loma Linda University Medical Center, *Loma Linda, California.*

Neonatal and pediatric respiratory disorders frequently require use of O_2H to deliver supplemental O_2. Little has been published about appropriate gas flowrates to prevent CO_2 rebreathing in O_2H. **Question:** We asked, what is the minimum gas flowrate necessary to maintain hood CO_2 < 0.5%? **Method:** We devised a system to simulate patient ventilation and CO_2 production ($\dot{V}_{CO_2}$) that included a patient gas flow at 350 mL · kg · min^{-1} simulating minute ventilation and CO_2 of 17.5 mL · kg · min^{-1} (approximately twice the normal CO_2 production) delivered to the hood through a mannequin head. Simulations were devised for 4 weights (1, 3, 5, and 10 kg) and 4 levels of $\dot{V}_E$ and $\dot{V}_{CO_2}$ through 3 different hood sizes (Peace Hoods) with dimensions of 9 in (729 in^3), 12 in (1,728 in^3), and 24 in (8 ft^3). Gas flow delivered to the hoods was kept constant at 5, 10, 15, and 20 L/min for the 9 and 12 in and 15, 30, 45, 60, and 75 L/min for the 24 in. CO_2 levels were measured by mass spec-

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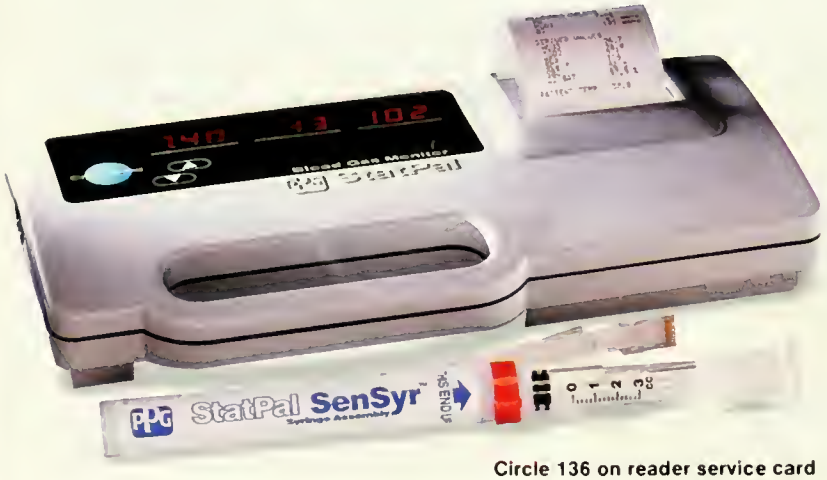

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trometry at 6 different locations within the hood at each flowrate. **Results:**

	L/min	Mouth	Left Cheek	Right Cheek	Forehead	Top Hood	Bottom Hood
1 kg	5	4.99	0.22	0.11	0.14	0.15	0.56
0.35 L/min	10	4.99	0.12	0.11	0.15	0.11	0.49
9-in Hood	15	4.99	0.10	0.10	0.12	0.10	0.45
	20	4.99	0.10	0.10	0.11	0.09	0.33
3 kg	5	4.99	0.23	0.24	0.56	0.17	0.22
1.05 L/min	10	4.99	0.20	0.35	0.37	0.17	0.22
12-in Hood	15	4.99	0.19	0.17	0.25	0.17	0.21
	20	4.99	0.23	0.22	0.30	0.18	0.17
5 kg	15	4.99	0.40	0.59	0.43	0.26	0.66
1.75 L/min	30	4.99	0.25	0.34	0.28	0.24	0.30
24-in Hood	45	4.99	0.25	0.21	0.39	0.20	0.21
	60	4.99	0.25	0.20	0.25	0.19	0.19
10 kg	30	4.99	0.37	0.48	1.20	0.33	1.09
3.5 L/min	45	4.99	0.60	0.52	0.58	0.32	0.32
24-in Hood	60	4.99	0.48	0.38	0.31	0.28	0.33
	75	4.99	0.27	0.30	0.29	0.24	0.25

Our results show that a flowrate of 10 L/min keeps the CO_2 levels < 0.5% in all tested areas in 9- and 12-in hoods, 30 L/min to clear ventilation of 24-in hood for a simulated 5-kg infant, and 60 L/min for a 10-kg infant. **Conclusions:** We conclude that CO_2 can be effectively reduced to a level < 0.5% at all but the lowest flowrates studied, and that gradients of CO_2 within the hoods do not significantly change with changes in hood flowrate. Perhaps better devices for gas mixing within the hoods are necessary to provide the most uniform mixture. (OF-91-131)

Ventilating the Sick Infant and Child

High-Frequency Oscillatory Ventilation (HFOV) Rescue in Neonates with Intractable Respiratory Disease—Patricia Shepperdson RRT, Frank Monaco BA RRT, Donald J Rommes MD, Keith S Meredith MD. Memorial Hospital, *Colorado Springs, Colorado.*

Introduction: Severe respiratory failure in the near-term infant remains a significant challenge in clinical neonatalogy. We report our retrospective review of a series of infants who required excessive conventional ventilator (CV) settings and were rescued with HFOV (3100, SensorMedics, Anaheim CA). **Methods**: 12 total patients were rescued (1 excluded because of cyanotic heart disease). All data are mean (SD). Diagnoses were ARDS = 7 (5 persistent pulmonary hypertension of the newborn [PPHN]) and RDS = 4 (1 PPHN); gestational age = 36.5 (1.6) wk; birthweight = 2778.6 (386.8) g, and age at rescue = 21.2 (10) h. CV settings prior to rescue were F_{IO_2} = 1.0 (0.01), MAP = 20.1 (3.4) cm H_2O, PIP = 40.7 (5.6) cm H_2O, PEEP = 5.8 (1.0) cm H_2O, and f = 62.5 (11.7) breaths/min. HFOV was managed to increase MAP in order to achieve optimal lung volume by chest x-ray while reducing F_{IO_2} to less than 0.7. Patients with PPHN were hyperventilated (P_{aCO_2} < 30 torr and pH > 7.45). **Results**: The table represents the pooled mean data for 4 hours prior to rescue (-4 to 0) and selected intervals afterwards. ANOVA was used to compare CV (-4 to 0) data to HFOV data. Survival was 100%. No patient experienced new pulmonary airleak or intracranial hemorrhage during rescue.

	-4 to 0 CV	0 to 1 HFOV	2 to 4 HFOV	5 to 8 HFOV	9 to 24 HFOV
F_{IO_2}	1.0	0.98	0.89	0.74*	0.56*
MAP	20.1	26.3*	25.9*	24.6*	21.4
OI†	45	31*	21*	15*	12*
P_{aO_2}/P_{AO_2}	0.096	0.202	0.295*	0.376*	0.418*
P_{aO_2}	49.6	104.3	140.5*	140.9*	107.8
P_{aCO_2}	34.6	29.4	27.4*	27.4*	30.4

*$p < 0.005$.

†$OI = (MAP)(F_{IO_2})(100/P_{aO_2})$.

Conclusions: In these patients, HFOV rescue resulted in a rapid improvement in gas exchange, no significant morbidity and no mortality. These data imply that HFOV should be considered in near-term infants failing CV. (OF-91-064)

Successful High-Frequency Jet Ventilation during Ambulance Transport—Kathleen Meyer RRT, Robert White MD, Linda Love RRT, Delores Tucker NNP. Memorial Hospital of South Bend, *South Bend, Indiana.*

Some newborns with severe respiratory distress benefit from high-frequency jet ventilation (HFJV) initially, but later become candidates for extracorporeal membrane oxygenation (ECMO). When HFJV was in its early stages, most centers doing research also had ECMO capability, so transport of critically ill infants on HFJV was not necessary. With more regional non-ECMO centers using HFJV, transport of critically ill infants on HFJV has become an issue. We report 4 cases of successful transport of infants on HFJV to an ECMO center. Case 1 was a term, 2300-g female with meconium aspiration syndrome (MAS), right pneumothorax, asphyxia, disseminated intravascular coagulation, and persistent pulmonary hypertension of the newborn (PPHN). After 20 h of satisfactory HFJV, O_2 saturation deteriorated and she was transferred to Riley Children's Hospital, a 3-h ground transport. Case 2 was a term, 3200-g male with MAS, ventricular septal defect, and PPHN. After 3 d of HFJV, during which his condition initially improved but then slowly deteriorated, he was transferred to Mott Children's Hospital, a 4-h transport. Case 3 was a term, 2140-g female with fetal distress, MAS, and PPHN. After 2 d of HFJV, she deteriorated hemodynamically and was transferred to Mott Children's Hospital, a 3.5-h transport. Case 4 was a 36-wk-gestation, 2820-g male with a diagnosis of Eagle-Barrett Syndrome, hypoplastic lungs, PPHN, and right pneu-

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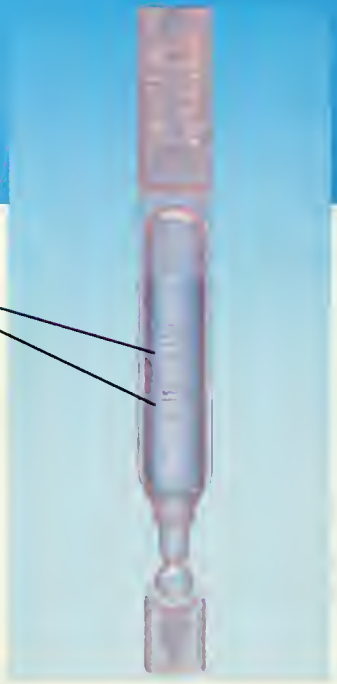

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mothorax. He was transferred on HFJV to Riley Children's Hospital, a 3-h transport. In each case, the infant's condition was very stable in transit, and no mechanical problems were experienced. Use of HFJV during transport entails prior assessment of the transport vehicle's capabilities; a generator, two "H" tanks (one air, one O_2), and secure placement of the jet ventilator next to a conventional ventilator are minimum requirements. An uninterruptible power supply is also desirable. When these conditions are fulfilled, transport of critically ill infants on HFJV can be safely accomplished when necessary. (OF-91-068)

Nasal Mask Ventilation of Two Young Pediatric Patients with Restrictive Lung Disease Associated with Kyphoscoliosis—Janet Dunaway RRT, The Children's Hospital of Alabama; J Clarke McIntosh MD, Robert A Schoumacher MD, The University of Alabama at Birmingham—*Birmingham, Alabama.*

Use of noninvasive nasal positive-pressure ventilation (NPPV) in adult patients with neuromuscular or restrictive chest-wall disease is an accepted alternative to tracheotomy or negative-pressure ventilation. We treated 2 pediatric patients (ages 6 and 9 y) with NPPV for management of chronic respiratory failure associated with severe kyphoscoliosis. Ventilatory muscle rest and reversal of chronic respiratory failure was accomplished with NPPV using a Puritan-Bennett 2801 portable volume ventilator. Consistent with the experience of other investigators using this therapy for pre-pubertal patients, we encountered problems with equipment selection, mask size, patient anxiety, and aerophagia. Success was defined as normalization of acid-base status, normal ventilation and sleep architecture during nocturnal polysomnography, and subjective improvement in activity and symptoms. The 6-year-old boy presented with P_{aCO_2} of 90 torr and the 9-year-old girl with P_{aCO_2} of 65 torr. After institution of nocturnal NPPV, these values were reduced to P_{aCO_2} of 44 torr for both patients during normal daytime activity while off support. Our first choice of support device was the Respironics S/T BiPAP unit. Due to the severe restrictive disease and small upper airways of these 2 patients, the BiPAP device delivered inadequate flow and pressure. The Puritan-Bennett 2801 ventilator with its higher pressures and rates was used successfully. Our teaching technique included slow introduction of the patients to the equipment to familiarize them with the tight-fitting mask and flow sensations of the ventilator. Prolonged daytime use of the mask was important in training the patients to synchronize their breathing with the ventilator. After achieving daytime intervals up to 4 h of restful NPPV, nocturnal use was initiated. Nocturnal polysomnography prior to discharge documented entrainment with the ventilator for both patients. O_2 saturation and P_{etCO_2} readings were normal throughout both studies, as was sleep architecture. Current ventilator settings for the 6-year-old are assist/control mode, V_T 420 mL, f 32, PEEP of 5, flowrate 48 L/min, sensitivity -1, and supplemental O_2 of 0.5 L/min. Current ventilator settings for the 9-year-old are assist/control mode, V_T 520 mL, f 32, flowrate 54 L/min, sensitivity -1, and supplemental O_2 of 0.5 L/min. With home use of NPPV, both patients returned to full-time school attendance with improvement in activity and endurance while maintaining a normal P_{aCO_2} at rest. Our experience suggests that reversal of chronic respiratory failure in this group of pediatric patients is possible with nocturnal NPPV. (OF-91-082)

Pressure Limiting a Volume Ventilator for a Chronic Ventilator-Dependent Child—Charolette Pickle RRT, Sami K W Hadeed MD, Cook-Fort Worth Children's Medical Center, *Fort Worth, Texas.*

This case involved a 6-mo, 5-kg boy with cerebro-costo-mandibular syndrome, tracheobronchomalacia, rib abnormalities, and upper-airway obstruction requiring a tracheotomy. He was transferred to our facility for discharge planning, including change to a portable ventilator (Lifecare PLV-100). The patient was stable on a Sechrist IV00B ventilator with settings PIP 30 cm H_2O, PEEP 8 cm H_2O, t_i 0.9 s, f 6, and F_{IO_2} 0.30. Attempted ventilation using the PLV-100 failed twice secondary to tachycardia and respiratory distress. It was surmised that the Sechrist ventilator was tolerated well because of the continuous flow and square waveform used. Using an airway pressure monitor (Novametric 1230A Pneumogard), we attempted to reproduce the same waveform with the PLV-100. Because the t_i is directly related to V_T and flow on the PLV-100, the small V_T that was required limited our ability to provide a longer t_i. Use of an external pressure limiter (Lifecare #6560) on the PLV-100 allowed us to deliver the desired t_i and waveform. This external pressure limiter is designed to be placed on the ventilator at the patient outlet, and limits the PIP independently of the set V_T. The patient stabilized on settings of PIP 30 cm H_2O, PEEP 8 cm H_2O, and t_i 0.76 s. This strategy allowed us to mimic pressure ventilation with a volume ventilator, making discharge of the patient on a portable ventilator possible. (OF-91-084)

Effect of Patient Flow-Triggered Ventilation (PFTV) Pulmonary Mechanics in Neonates—Kelvin D MacDonald RCP, Elizabeth Salaz RRT, Peter B Wang CRTT, Ralph Franceschini MD, Kaiser Permanente Medical Center, *Los Angeles, California.*

Assist-control (A/C) ventilation has been shown to improve oxygenation in infants (Arch Dis Child 1988;63:394-397) attributed to increased insufflation volumes that may be a result of changes in pulmonary mechanics. We evaluated changes in oxygenation and pulmonary mechanics during neonatal A/C. **Methods:** 4 patients (birthweight 1200-2956 g) currently on IMV were placed on the Bear Cub II PFTV (Riverside CA). A hot-wire anemometer was used to detect flow at the airway and determine pulmonary mechanics. A Med-Science pulmonary function cart (St Louis MO) recorded and analyzed the signals. S_{pO_2} (via Nellcor, Hayward CA) was analyzed by computerized pulse oximetry software (EMG Scientific, Beverly Hills CA); P_{tcCO_2}, O_2, and mean airway pressure (MAP) were also recorded. Data were captured con-

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tinuously for 1 h on CMV, then for 1 h on A/C. Mean data were evaluated via paired *t* test. **Results:**

	$\dot{V}_E$ (L)	C_{rs} (mL/cm H_2O)	S_{pO_2} (%)	P_{tcCO_2} (torr)
Before	0.923	1.15	90	50
After	1.24	1.25	96	43
	$p < 0.02$	$p > 0.05$	$p < 0.02$	$p < 0.02$

There was an insignificant increase in MAP. No adverse effects were noted. **Discussion:** The increases in $\dot{V}_E$ were a result of the increased mechanical rate due to patient triggering during A/C. The significant increase in S_{pO_2} is probably a result of increased positive-pressure inflations and alveolar ventilation. **Conclusion:** Neonatal AC ventilation appears to have improved S_{pO_2} in these patients without a significant change in lung mechanics or MAP. Longer controlled trials are needed to determine the clinical usefulness of neonatal A/C. (OF-91-155)

SIMV Improves Oxygenation in Neonates—Kelvin D MacDonald RCP, Peter B Wang CRTT, Elizabeth Salaz RRT, David D Wirtschafter MD. Kaiser Permanente Medical Center, *Los Angeles, California.*

Others have reported improvements in oxygenation in neonates when using synchronized assist-control (A/C) ventilation. This has been attributed to improved alveolar volume delivery, although at increased mechanical rates. A new abdominal motion patient-triggered ventilator (PTV) (Infrasonics, San Diego CA) that provides SIMV was studied for its ability to improve oxygenation by reducing F_{IO_2} within a given range of S_{pO_2}. **Methods:** 10 stable infants ≥ 1.0 kg ($\bar{x}$ = 1.9, SD = 0.7) with IMV rates ≥ 20 breaths/min, breathing ≥ 30 breaths/min spontaneously, were studied in 2 successive 3-h periods. An Infant Star ventilator with the trigger module provided IMV during the first phase and SIMV in the second phase. Routine care was provided to the patients during each phase. The F_{IO_2} was recorded and adjusted to maintain S_{pO_2} 90-95% using a pulse oximeter (Nellcor, Hayward CA) whose output was recorded and analyzed by computerized pulse oximetry software (EMG Scientific, Beverly Hills CA). Patients were also monitored with transcutaneous CO_2 and O_2 electrodes (SensorMedics, Yorba Linda CA). Spontaneous respiratory rate was recorded, all other settings remained unchanged in both periods. **Results:** Mean (SD) values were F_{IO_2} (pre/post) 62 (12)/48 (21); S_{pO_2} (pre/post) 93 (4)/92 (30; spontaneous f (pre/post) 38 (5)/33 (4). F_{IO_2} at the end of each period was evaluated using a paired *t* test ($t = 3.284$; $p < 0.01$). 8 of 10 patients responded with a reduction in F_{IO_2} within the S_{pO_2} range; 2 infants required F_{IO_2} increases of 3% and 18%, respectively. Changes in P_{tcCO_2} in each period were unremarkable. **Discussion:** Reductions in F_{IO_2} are presumed to be a result of improved alveolar volume delivery with synchronous ventilation. This small group suggests a direct benefit from a PTV with our patient-selection criteria without the reported increase in mechanical rate. Further long-term evaluation in a more diverse population is needed. (OF-91-156)

The Effects of Inspiratory Time (t_i) on Simulated Hand Ventilation through Pediatric Endotracheal Tubes (ETT)—Darrell Benham RRT, Arkansas Children's Hospital; Elizabeth Moudy, UAMS/CHRP—*Little Rock, Arkansas.*

We studied the effect of short t_i and fast flowrates on V_T when various sizes of ETT were used. **Methods:** Utilizing the Servo 900C (SIMV mode), connected to a Bio-Tek Model VT-2 lung simulator by various sizes of ETT, the V_T delivered was measured while the t_i% was adjusted stepwise on the 900C from 50% to 20%. In the 900C, by design in the SIMV mode, V_T is constant and flow increases as the t_i% is decreased. Settings chosen were V_T 120 mL, f 10, PEEP 5 cm H_2O, F_{IO_2} 1.0, $\dot{V}_E$ 4.8 L. The peak P_{aw} was measured for each size tube (t_i50%). This value was then set on the Upper Pressure Limit Knob to attain a constant pressure delivered to the lung. The t_i was then decreased, and the resulting V_T delivered by the 900C was recorded for 6 trials for each size tube and t_i%. **Results:**

ETT Size	t_i%	Paw (torr)*	V_T (mL)	t_i (s)	$\dot{V}$ (L/min)
3.0	50%	41.9 (0.25)	0.11 (0.00)	0.7 (0)	9.2 (0.37)
	33%	42.7 (0.35)	0.07 (0.002)	0.3 (0)	13 (0.58)
	25%	42.9 (0.49)	0.03 (0.002)	0.1 (0)	12.7 (1.37)
	20%	43.1 (0.19)	0.02 (0.002)	0.1 (0)	12.8 (1.21)
3.5	50%	38.5 (0.15)	0.11 (0.000)	0.7 (0.0)	9.0 (0.0)
	33%	39 (0.55)	0.08 (0.003)	0.4 (0.0)	13.3 (0.5)
	25%	38.3 (0.41)	0.04 (0.002)	0.2 (0.04)	15.2 (0.7)
	20%	38.7 (0.25)	0.03 (0.0)	0.1 (0.0)	14.2 (0.7)
4.0	50%	37.2 (0.31)	0.11 (0.0)	0.8 (0.1)	8.5 (1.1)
	33%	37.6 (0.37)	0.09 (0.0)	0.5 (0.03)	13.3 (0.7)
	25%	36.9 (0.25)	0.06 (0.0)	0.2 (0.0)	16.7 (0.5)
	20%	36.7 (0.22)	0.04 (0.0)	0.1 (0.0)	17.0 (1.2)
4.5	50%	36.3 (0.20)	0.11 (0.0)	0.7 (0.0)	9.0 (0.0)
	33%	37.1 (0.40)	0.10 (0.0)	0.4 (0.0)	13.8 (0.4)
	25%	36.7 (0.44)	0.07 (0.0)	0.2 (0.0)	18.2 (0.4)
	20%	36.3 (0.93)	0.06 (0.0)	0.2 (0.0)	19.0 (1.0)
5.0	50%	36.0 (0.18)	0.11 (0.0)	0.7 (0.0)	9.0 (0.0)
	33%	37.2 (0.31)	0.10 (0.0)	0.4 (0.1)	13.8 (0.4)
	25%	36.2 (0.51)	0.08 (0.0)	0.3 (0.0)	18.5 (0.8)
	20%	36.3 (0.76)	0.07 (0.0)	0.2 (0.0)	21.0 (0.6)

*All values are mean (SD); all measurements made at BTPS

Conclusion: The results demonstrate a direct relationship between V_T and t_i, and an indirect relationship between V_T and flowrate. The effect on V_T was greater in the smaller diameter ETT. We believe that if one is attempting to simulate ventilator V_T with a resuscitation bag and manometer, one should also attempt to simulate the t_i and flowrates of the ventilator to assure proper V_T to the patient. (OF-91-113)

Intratracheal Pulmonary Ventilation: A Case Report—Jay M Wilson MD, John E Thompson RRT, Lynne K Bower RRT,

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Jay Schnitzer MD. Children's Hospital, *Boston, Massachusetts.* CW Lillehei MD, T Kolobow MD. National Institutes of Health, *Bethesda, Maryland.*

Previously reported data indicate that neonates with congenital diaphragmatic hernia (CDH) who demonstrate a best postductal P_{aO_2} ($BPDPO_2$) of < 100 torr on maximum conventional mechanical ventilation (CMV) have a mortality exceeding 90%. Despite resuscitation with ECMO, mortality increases to 100% if the infants develop hypercarbia (P_{aCO_2} > 36 torr) after decannulation. Historically, these patients have required increasing ventilator support leading to iatrogenic lung damage and death. Intratracheal pulmonary ventilation (ITPV), developed by Kolobow, incorporates a continuous flow of humidified gas thru a reverse venturi catheter positioned at the distal end of the ETT. It has been reported to reduce anatomical dead space (VD) and facilitate expiration and CO_2 elimination in animal studies. We report ITPV application on 3 separate occasions (18 hours total) in a single neonate with CDH who met the above criteria for 100% mortality. **Case Summary:** A full-term neonate with CDH and a $BPDPO_2$ of 38 torr required 2 consecutive courses of ECMO therapy. Failure in each case was due to reoccurrence of respiratory acidosis secondary to rising P_{aCO_2}. On 2 separate occasions while the infant remained on ECMO with the circuit clamped, ITPV was tested. Subsequently, ITPV was used on a third occasion 24 hours after successful decannulation to CMV because of a sudden sharp rise in P_{aCO_2}. In each instance, ITPV achieved better alveolar ventilation and lower P_{aCO_2} at lower PIP than CMV. After the third trial of ITPV, which was employed for 6 consecutive hours, CMV was successfully reinstituted with the child eventually weaning to spontaneous unassisted ventilation without recurrence of hypercarbia. We conclude that (1) ITPV can be utilized successfully in infants with CDH; (2) ITPV achieved this reduction in P_{aCO_2} at lower PIPs than CMV; and (3) ITPV is a powerful new tool that should be considered for clinical trials to further evaluate its efficacy. (OF-91-115)

Bronchodilator Aerosols

The Volume of Gas Emitted from Metered Dose Inhalers (MDIs)—Dean Hess MEd RRT, Ann Daugherty BS RRT, Mark Simmons MS RPFT RRT. York Hospital, *York, Pennsylvania.*

Study Question: What is the volume of gas emitted from commonly used MDIs? **Methods**: We studied Alupent (Boehringer Ingelheim), Atrovent (Boehringer Ingelheim), Beclovent (Allen & Hanburys), Intal (Fisons), and Ventolin (Allen & Hanburys). The test system consisted of plastic bag (Dow Ziploc pleated storage bag), Instrumentation Industries RTC 23-D MDI adapter, 4-way stopcock, and 60-mL calibrated syringe. The system was glued together (Duro Household Cement), and absence of leaks confirmed by underwater testing. Each evaluation consisted of 10 puffs from the MDI into the bag, after which the volume in the bag was determined using the syringe, and the volume/puff calculated by dividing by 10. Each type of MDI was evaluated at 3 levels of fullness: nearly full, partially empty, and nearly empty. The Intal MDI (contains 112 puffs when full) was evaluated at 1-10 puffs (nearly full, ≈102-112 puffs remaining in MDI), 51-60 puffs (partially empty, ≈52-61 puffs remaining), and 91-100 puffs (nearly empty, ≈12-21 puffs remaining). The other MDIs (each contain 200 puffs when full) were evaluated at 1-10 puffs (nearly full, ≈191-200 puffs remaining in MDI), 91-100 puffs (partially empty, ≈100-109 puffs remaining in MDI), and 181-190 puffs (nearly empty, ≈10-19 puffs remaining in MDI). The MDIs were shaken before each activation, and 5 evaluations were made with each MDI brand (using a new MDI canister for each set of measurements). Mean (SD) volumes were calculated, as well as two-way analysis of variance using MDI brand as a grouping variable and volume remaining in the MDI (full, partially empty, nearly empty) as a repeated measures factor. **Results**: The mean (SD) volumes (mL) emitted from each MDI at each level are shown below.

MDI	nearly full	partially empty	nearly empty
Alupent	15.6 (0.4)	15.2 (0.1)	14.7 (0.2)
Atrovent	14.8 (0.2)	14.5 (0.1)	14.7 (0.2)
Beclovent	17.2 (0.3)	17.1 (0.3)	17.2 (0.2)
Intal	14.7 (0.3)	14.9 (0.2)	14.8 (0.3)
Ventolin	19.8 (0.4)	19.5 (0.4)	19.3 (0.3)

There was a significant difference in the volumes emitted between MDI brands ($p < 0.001$) and the levels of fullness ($p = 0.001$). There was a significant interaction between MDI brand and level of fullness ($p = 0.001$). **Conclusions:** The volume of gas emitted from these MDIs was small (eg, 15-20 mL) and is too small to be clinically important in the care of adult patients. The volume of gas emitted from an MDI can be potentially important if MDIs are used with very small tidal volumes in a closed system (eg, infants). Although statistically significant, the differences in volume between levels of fullness were not clinically important. (OF-91-028)

The Effect of Diluent upon Aerosol Characteristics—Grey Benton MA RRT, Robert Kim Woodward BS RRT, Nancy Lewis MD. Oakland Children's Hospital, *Oakland, California.*

We replaced normal saline with water for bronchodilator dilution and studied the effect on aerosol mass/L, percentage of respirable particles, number of particles/mL, and particle diameter. 6 solutions were prepared using standard aerosol treatment proportions of metaproterenol (Alupent) and albuterol, diluted with water and saline. 45-mL aliquots were nebulized using a SPAG II nebulizer without a drying chamber. Each aerosol was analyzed 3 times with a TSI Aerodynamic Particle Sizer (Model 3300). **Results:** Average results are shown.

	Diluted with:	2.5 mL saline	2.5 mL water
No drug (control)	Aerosol mass:	353.3 μg/L	3.8 μg/L
	% Respirable:	93.8%	33.1%
	# particles:	706667/mL	185/mL
	Mean diameter:	0.88 μm	2.47 μm

	Diluted with:	2.5 mL saline	2.5 mL water
0.5 mL Albuterol (0.5%)	Aerosol mass:	404.7 μg/L	185.0 μg/L
	% Respirable:	81.7%	33.6%
	# particles:	714333/mL	29300/mL
	Mean diameter:	0.87 μm	1.24 μm
0.3 mL Alupent (5.0%)	Aerosol mass:	553.0 μg/L	263.3 μg/L
	% Respirable:	80.5%	44.3%
	# particles:	916667/mL	264333/mL
	Mean diameter:	0.88 μm	0.80 μm

The aerosol mass/L, the percent aerosol that is respirable (able to reach the airways), and the number of particles/mL of gas were greater when saline was used instead of water. The mean aerodynamic diameter of the particles was smaller when saline was used instead of water, except with metaproterenol and then the diluent made very little difference. We conclude that saline is an important component of solutions for aerosol therapy and that replacing saline with another diluent can change the characteristics of the aerosol. (OF-91-036)

Titration for Optimal Dose Response to Bronchodilators Using MDI and Spacer in Ventilated Adults—James B Fink MS RCP RRT, Neal H Cohen MD, Jack Covington BS RCP, Michael J Mahlmeister MS RCP RRT. UCSF Medical Center, *San Francisco, California.*

Patients who require mechanical ventilation often have bronchospasm requiring treatment. The optimum method of administering bronchodilators (BDs) to intubated patients is unclear. Many practitioners now use BDs administered via MDI. Several studies have documented decreased deposition of aerosols associated with the presence of endotracheal tubes and the physical characteristics of ventilator circuits. As a result, large doses of BDs may be necessary for the intubated, ventilated patient. We implemented a clinical protocol for titrating BD dosage to determine the optimal dose required to achieve a clinical response in ventilated patients. **Method**: 85 adult ventilated patients with orders for aerosolized albuterol (Proventil, Schering Corp, Kenilworth NJ) had MDI administration with an Aerovent spacing device (Monaghan Medical Corp, Plattsburgh NY) placed in the inspiratory line of the ventilator circuit. Patients were given 2 series of 10 puffs at 5-min intervals, followed by 4 series of 5 puffs, up to a maximum of 40 puffs. Parameters including heart rate, arrhythmias, respiratory rate, blood pressure, presence of tremor, breath sounds, PIP, plateau pressure ($P_{plateau}$), mean airway pressure (MAP), inspiratory resistance (R_I) and auto-PEEP were monitored before initial administration and following each series of puffs. Puffs were administered 20-30 seconds apart at beginning of inspiration. Series of puffs were repeated until dosage reached 40 puffs, heart rate increased > 20% from baseline, arrhythmias were noted, or tremor developed. Optimal response was defined as the dose at which the greatest improvement in one or more of the monitored parameters was achieved. When subsequent puffs did not yield greater improvement, titration was stopped. **Results:** 85 patients received an average total dose of 34 puffs (range 10-35). 51 patients (60%) demonstrated a positive response to therapy with average optimal response at 22.2 puffs; 34 patients (40%) demonstrated no measurable or subjective improvement after 40 puffs. 35/85 patients had a history of smoking or reversible airway disease, and only 6 of these (17%) did not respond to the maximum titrated dose. 4 patients experienced adverse or toxic responses at an average of 23.7 puffs (range 10-35). 2 patients developed increased heart rate (92-128 at 10 puffs and 78-96 at 35 puffs), and 2 patients had continued or increased PVCs with the titration. All adverse responses resolved spontaneously within 5 min of onset and did not require treatment. Initial titrations required an average 45 min. Medication costs for 40 puffs is approximately $1.20 for the total treatment. **Conclusion:** The number of puffs required to produce objective evidence of optimal response is higher than anticipated, and a large percentage of patients have a defined clinical threshold of response with no toxic reaction. Toxicity, if it occurs at all, is minimal and does not require treatment, except discontinuation. No other morbidity or mortality was associated with titrated doses. (OF-91-039)

Titration for Optimal Dose Response of Albuterol Using MDI and Spacer in Non-Intubated Adults—James B Fink MS RCP RRT, Neal H Cohen MD, Jack Covington BS RCP, Michael J Mahlmeister MS RCP RRT. UCSF Medical Center, *San Francisco, California.*

Non-intubated patients who require bronchodilatator therapy are commonly treated in the hospital with metered-dose inhaler (MDI). We describe a clinical protocol designed to determine the optimal dose of albuterol administered via MDI with spacer. **Methods**: Using albuterol MDI (Proventil, Schering Corp, Kenilworth NJ) with the Aerochamber spacer (Monaghan Medical Corp, Plattsburgh NY), we titrated the dose for optimal response in 100 adult patients with orders to receive aerosolized therapy. Patients were given a series of 4 puffs at 5-min intervals up to a maximum of 20 puffs. Individual puffs were administered on inspiration, 20-30 s apart. Heart rate, respiratory rate, breath sounds, peak flow or FEV_1, and subjective response were monitored before initial administration and following each series of puffs. Series were repeated until pulse rate increased > 20%, arrhythmias were noted, tremor developed or dosage reached 20 puffs. Initial response was defined as > 10% increase in peak flow or FEV_1, or a discernible improvement in breath sounds or subjective response. Optimal response was defined as dose at which response was greatest in 1 or more of the monitored parameters. When subsequent puffs did not yield greater improvement, titration was stopped. **Results:** 100 patients received an average dosage of 14.5 puffs (range 2-20). 92 patients demonstrated a positive response to therapy with average initial response at 5.2 puffs (range of 2-12) and average optimal response at 10.3 puffs. 8 patients demonstrated no measurable or subjective improvement. 20 patients experienced adverse or toxic responses at an average of 12.8 puffs (range 4-20). 11 patients developed light to mod-

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erate tremor, 4 patients experienced 20% increase in pulse rate, 3 patients became light-headed or dizzy, and 1 patient complained of palpitations and fatigue. Subsequent treatments were given at the optimally determined dose with 20-30 s between puffs. No adverse responses were reported. Initial titrations required an average of 30 min. All adverse responses resolved spontaneously within 5 min of onset. Subsequent treatment averaged 6 min vs 15-20 min for standard small volume nebulizer treatments (SVN), with no important increase in medication costs. **Conclusions**: Number of puffs required to demonstrate objective evidence of optimal response in non-intubated adults is often as high as 20 puffs. A large percentage of patients see a clinical threshold of response between 2 and 20 puffs with no toxic reaction. Toxicity, if it occurs at all, is minimal and does not require treatment other than discontinuation. No other morbidity or mortality was associated with titrated doses. Titration of dose using MDI with spacer may have implications for reducing costs of respiratory care in the treatment of the acute bronchospastic patient: although initial titrations are time-consuming, subsequent treatments require less therapist time. (OF-91-040)

Improved Efficacy of Hand-Held Nebulizers with Inspiratory Reservoirs of Increased Length—Paul Stephan RRT, Fran Evans, Laurie Goslinga, Wendy Stritch, Deborah A Holt. Santa Fe Community College, *Gainesville, Florida.*

We investigated how changes in length of inspiratory reservoirs affected the aerosol delivery of a hand-held nebulizer at varying V_Ts. **Methods:** To simulate spontaneous patient breathing, an Emerson Post-Op Ventilator was connected to one side of a Training Test Lung (TTL). A Pall filter was connected to the other side of the TTL to trap the aerosolized solution. Two test groups were run with a 4-mL solution of normal saline aerosolized for 6 min at 8 L/min. Group I utilized a 13.5 cm (50 mL) reservoir and Group II a 203 cm (760 mL) reservoir. Each group had 6 trials at V_Ts of 350 and 530 mL for a combined total of 24 trials. **Results:** Group I showed little difference in amount of solution trapped on the filter paper for the two V_Ts studied. Group II showed the amount of solution trapped on filter paper was increased significantly ($p < 0.05$) over that of Group I for both V_Ts. Group II demonstrated a significant difference ($p < 0.05$) in aerosol delivery over Group I at 350 and 530 mL, respectively. **Conclusion:** Increasing V_T as well as inspiratory reservoir length significantly improves the amount of aerosolized solution available for inspiration.

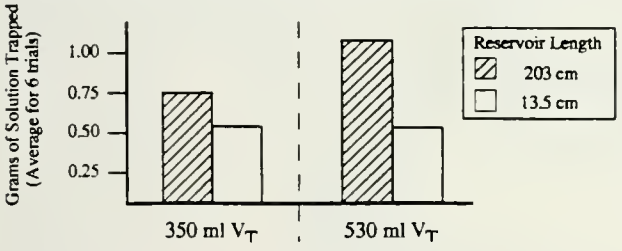

Fig. 1. Comparison of solution trapped on the basis of V_T and reservoir length. (OF-91-100)

More studies are needed to evaluate whether increasing the total amount of bronchodilator delivered will enhance its efficacy in the clinical setting (see Fig. 1).

Treatment of Status Asthmaticus with Continuously Aerosolized Albuterol—N Tate Bennett CRTT, Cape Fear Valley Medical Center, *Fayetteville, North Carolina.*

Some patients with status asthmaticus require mechanical ventilation despite standard therapy that typically includes intermittent aerosolization of a beta agonist, aminophylline infusion, and systemic steroids. My RC Dept has developed a method of delivering high-dose, continuously aerosolized albuterol that has been effective in avoiding mechanical ventilation. Twenty-four patients with severe respiratory distress (including substernal retractions, poor air movement, wheezing, deteriorating arterial blood gases, and decreased O_2 saturation not responding to standard treatment) were administered high-dose albuterol aerosolized continuously at 0.6 mg/kg/h. Albuterol mixed with 0.45% saline in a buretrol was dripped into a small volume nebulizer. O_2 flow was maintained at 6-8 L/min. Heart rate, f, O_2 saturation, and peak flow were monitored every 30 min. Mean (SD) length of treatment was 3.9 (0.4) h. Peak flow increased from 89 (82) L/min, f decreased from 38 (14) to 29 (14) breaths/min, heart rate increased from 138 (36) to 141 (36) beats/min, and O_2 saturation increased from 95 (5) to 99 (3) %. Decreased wheezing, increased air movement, and absence of respiratory distress were noted in all patients upon termination of high-dose albuterol aerosolized continuously. There were no obvious side effects of the high-dose albuterol (such as increased heart rate, nervousness, or nausea). In our 24 patients, intervention with high-dose albuterol aerosolized continuously appeared to be safe and efficacious. (OF-91-125)

Comparison of Aerosol Delivery via Two MDI Adapters during Mechanical Ventilation—Thomas A Barnes EdD RRT, Nancy Chen PhD. Northeastern University, *Boston, Massachusetts.*

We compared the amount of MDI-generated aerosol that penetrates a 9-mm endotracheal tube (ETT) during MV using the Boehringer Laboratories 9056 nondisposable Bronchodilator Tee and Monaghan disposable AeroVent holding chamber. **Method:** AeroVent ($3.95) and Boehringer ($71.50) were evaluated to determine the amount of respirable (1-4 μm) aerosol penetrating a 9-mm anatomically shaped ETT when used with an MDI. Both MDI adapters were used with an Intertech Volume Ventilator Circuit model 003280 attached to a Bennett MA-1. Boehringer was placed between the Y and the ETT. AeroVent was placed in the inspiratory limb proximal to the Y and attached to the ETT with 6 in of disposable aerosol tubing. A Bennett Cascade I was used to humidify the inspiratory gas to 33°C measured proximal to the Y. The ventilator delivered 1 L into the circuit at a flow of 30 L/min. V_T and $\dot{V}$ were verified using a calibrated Timeter RT-200. A calibrated 6-stage cascade impactor (California Measurements Model AS-6,

Sierra Madre CA) was used to characterize the aerosol penetrating the ETT. This unit through which air was drawn at 12.5 L/min was fitted with evaporation chamber (EC). EC was modified from a 3-L round-bottom distillation bottle by addition of another port. The diameter of the EC was 16 cm. MDI adapters were tested using a nonaqueous suspension aerosol described by Dalby and Byron (Pharm Res 1988;5:36-39). The aerosol contains 1.09% micronized disodium fluorescein (DF) as the model drug, stabilized by 1.0% sorbitan triolate in a blend of fluorocarbons (29.37% and 68.53% Freon 11 and 12, respectively). A 50-μL metering valve (Bespak, Carry NC) was used throughout, and each spray contained 754 μg of DF. The actual amount of DF delivered through stem orifice was corrected for the actual sample weight. The MDI was actuated midway through a 2-s inspiration emitting spray into a continuous gas flow. Following 10 actuations spaced at 6-s intervals (cannister shaken vigorously after every 2 puffs) the DF deposited in the MDI adapter, Y, expiratory limb, ETT, EC, and each stage of cascade impactor was determined spectrophotometrically at 488.5 nm. **Results:**

	% Output from ETT*			
	Total	EC	Impactor	Respirable† (1-4 μm)
Boehringer	2.40 (1.16)	1.48 (1.22)	0.93 (0.24)	0.87 (0.23)
AeroVent	1.50 (0.34)	0.34 (0.32)	1.16 (0.09)	1.11 (0.08)

	% Elsewhere*			
	ETT	Extension Tube	Y	Adapter
Boehringer	80.15 (0.56)	—	—	17.44 (0.78)
AeroVent	4.52 (0.41)	5.52 (0.53)	9.75 (4.72)	78.63 (5.97)

* Percentage of dose emitted from 50-μL metering valve. Mean (SD) of three replicates.
† The respective mass median aerodynamic diameter (SD) was determined to be 1.64 (0.12) and 1.54 (0.03) when using Boehringer and AeroVent MDI adapters.

No significant difference existed between the total and respirable aerosol penetrating the ETT when the Boehringer was compared to the AeroVent (ANOVA, $p = 0.26$ and 0.16, respectively) but a signficant difference in aerosol impacting in the ETT (ANOVA, $p < 0.0001$). **Conclusion:** AeroVent prevents large nonrespirable particles from impacting in the ETT. Further study appears to be warranted to determine the appropriate dose for different adapters used for MDI-generated aerosol during MV. (OF-91-160)

Effect of a New Nebulizer Position on Aerosol Delivery during Mechanical Ventilation—William W Quinn, Alton Ochsner Medical Foundation, *New Orleans, Louisiana.*

In light of recent research, I sought to demonstrate an inexpensive in-vitro model of aerosol delivery to the ventilated patient and to use this model to evaluate a new nebulizer position. **Method:** Filters treated with yellow coloring were placed in a trap position between the endotracheal tube and the test lung. Blue food coloring was nebulized while the ventilator cycled. Results were generated by single-blind scoring of test filters against a scale of 30 yellow filters exposed to nebulized blue coloring for timed periods in 5-s increments. 10 trials in each of 5 test groups were conducted to study the effects of mode and position. **Results:** Group 1 (continuous flow with nebulizer 90 cm from patient Y) mean (SD) score was 8.2 (0.75). Group 2 (continuous flow with nebulizer 180 cm from Y) was 11.8 (0.6). Group 3 (intermittent flow with nebulizer 90 cm from Y) was 1.8 (0.4). Group 4 (intermittent flow, same position, but with simulated spontaneous breathing added to take advantage of the 7200 ventilator's nebulizing on every breath) was 4.9 (0.7). Group 5 (continuous flow with nebulizer 180 cm from Y, with simulated spontaneous breathing as in Group 4) 12.8 (0.98). **Conclusion:** Continuous nebulization 180 cm from the Y (directly on the ventilator connection) offers the patient significantly more medication than either continuous or intermittent nebulization 90 cm from the Y ($p < 0.001$), even when the ventilator is intermittently nebulizing on spontaneous breaths. (OF-91-147)

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Notices of competitions, scholarships, fellowships, examination dates, new education programs, and the like will be listed here free of charge. Items for the Notices section must reach the Journal 60 days before the desired month of publication (January 1 for the March issue, February 1 for the April issue, etc). Include all pertinent information and mail notice to RESPIRATORY CARE Notices Dept, 11030 Ables Lane, Dallas TX 75229-4593.

Notices

THE ALLEN AND HANBURYS PUBLICATIONS AWARDS FOR 1991

1. $2,000 for the best original paper (study, evaluation, or case report) accepted for publication in RESPIRATORY CARE from November 1990 through October 1991.

2. Four awards of $1,000 each for papers based on 1990 OPEN FORUM presentations accepted for publication in RESPIRATORY CARE from November 1990 through October 1991.

3. Five awards of $500 each for the best papers (submitted, not necessarily published) from 'never published in RC' OPEN FORUM participants. The author must present the abstract at the Annual Meeting and must submit a paper based on the abstract *before* the Annual Meeting (received in the Editorial Office by December 1).

REGISTRATION REIMBURSEMENT FOR OPEN FORUM PAPERS

Any 1991 OPEN FORUM presenter (or co-author designee) who submits an adequately prepared paper based on his or her OPEN FORUM presentation *prior to* or *at* the 1991 Annual Meeting will be reimbursed for Annual Meeting registration. The submitted paper must contain complete data, be appropriately organized, and be typed double-spaced. Camera-ready artwork need not be submitted with the paper, but sketches of proposed figures should be clear and detailed enough to allow critique.

RADIOMETER AMERICA

Radiometer America Inc is offering three awards of $333 each for the best features from (1) Test Your Radiologic Skill, (2) Blood Gas Corner, and (3) PFT Corner accepted for publication from November 1990 through October 1991.

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1992—San Antonio, Texas, December 12-15

1993—Nashville, Tennessee, December 11-14

1994—Las Vegas, Nevada, December 12-15

1995—Orlando, Florida, December 2-5

PUBLICATION OF INTEREST

"Children's Exposure to Environmental Cigarette Smoke Before and After Birth—Health of Our Nation's Children, 1988." MMWR 1991;40:504.

Single copies of this document are available from the Scientific and Technical Information Branch, NCHS, CDC, Room 1064, 6525 Belcrest Road, Hyattsville MD 20782. (301) 436-8500.

THE NATIONAL BOARD FOR RESPIRATORY CARE—1992 Examination and Fee Schedule

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EXAMINATION DATE:	MARCH 14, 1992
Applications Accepted Beginning:	November 1, 1991
Application Deadline:	January 1, 1992
EXAMINATION DATE:	JULY 18, 1992
Applications Accepted Beginning:	March 1, 1992
Application Deadline:	May 1, 1992
EXAMINATION DATE:	NOVEMBER 14, 1992
Applications Accepted Beginning:	July 1, 1992
Application Deadline:	September 1, 1992

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EXAMINATION DATE:	JUNE 6, 1992
Applications Accepted Beginning:	December 1, 1991
Application Deadline:	February 1, 1992
EXAMINATION DATE:	DECEMBER 5, 1992
Applications Accepted Beginning:	June 1, 1992
Application Deadline:	August 1, 1992

RPFT Examination

EXAMINATION DATE:	DECEMBER 5, 1992
Applications Accepted Beginning:	July 1, 1992
Application Deadline:	September 1, 1992

CPFT Examination

EXAMINATION DATE:	JUNE 6, 1992
Applications Accepted Beginning:	December 1, 1991
Application Deadline:	April 1, 1992

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EXAMINATION DATE:	MARCH 14, 1992
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Application Deadline:	November 1, 1991
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Pressure Support During Mechanical Ventilation
January 28, 1992, 11:30 a.m.-1:00 p.m. Eastern
Neil R. MacIntyre, MD, and David J. Pierson, MD

- Understand what pressure support is and how it differs from other methods of applying pressure to the airway.
- Learn the clinical situations in which pressure support may be useful.
- Understand how pressure support is used during ventilator weaning.
- Learn how to determine appropriate levels of pressure support in different clinical situations.

Hemodynamic Monitoring
March 31, 1992, 11:30 a.m.-1:00 p.m. Eastern
John J. Marini, MD, and David J. Pierson, MD

- Know the different forms of invasive and noninvasive hemodynamic monitoring currently used in intensive care.
- Learn how to determine what level of monitoring is appropriate for a given patient.
- Understand how positive end-expiratory pressure and other therapies affect hemodynamic parameters.
- Know the main complications of invasive hemodynamic monitoring.

Weaning from Mechanical Ventilation
May 6, 1992, 12:30-2:00 p.m. Eastern
Martin J. Tobin, MD, and David J. Pierson, MD

- Know the different basic approaches to ventilator weaning and how they differ.
- Understand the differences in weaning from short-term and long-term mechanical ventilation.
- Know the principal respiratory measurements used in predicting ability to wean and how to interpret them.
- Know the main causes for weaning failure.

Pulmonary Rehabilitation
July 9, 1992, 12:30-2:00 p.m. Eastern
Barry Make, MD, and David J. Pierson, MD

- Know the components of a comprehensive rehabilitation program.
- Understand how to select appropriate candidates for pulmonary rehabilitation.
- Learn how to identify and set both short-term and long-term goals for patients.
- Know how to assess a patient's progress and follow-up.

Aerosol Administration
September 25, 1992, 12:30-2:00 p.m. Eastern
Dean Hess, MEd, RRT, and David J. Pierson, MD

- Know the basic principles underlying the therapeutic use of drugs by the aerosol route.
- Understand the differences in efficacy and use of metered-dose inhalers vs. nebulizers.
- Learn how to administer and assess the effects of bronchodilators during mechanical ventilation.
- Learn techniques for correct use of aerosol devices by patients.

Prevention of Postoperative Atelectasis and Pneumonia
November 17, 1992, 12:30-2:00 p.m. Eastern
Richard D. Branson, RRT, and David J. Pierson, MD

- Understand the pathogenesis of postoperative atelectasis and pneumonia.
- Learn how to identify patients at increased risk for developing postoperative atelectasis and pneumonia.
- Know how to decrease the risk of nosocomial pneumonia in intubated ICU patients.
- Understand the roles of chest physiotherapy, bronchoscopy, and other therapies in managing acute lobar atelectasis.

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About the Presenters

- **David J. Pierson, MD** — Medical Director of Respiratory Care, Harborview Medical Center. Assistant Professor of Medicine, University of Washington, Seattle, WA.
- **Neil R. MacIntyre, MD** — Medical Director of Respiratory Care Services, Duke University Medical Center, Durham, NC. Assistant Professor of Medicine, Duke University Medical Center, Durham, NC.
- **John J. Marini, MD** — Professor of Medicine, University of Medicine. Director of Pulmonary/Critical Care, St. Paul-Ramsey Medical Center, St. Paul, MN.
- **Martin J. Tobin, MD** — Professor of Medicine, Loyola University of Chicago Stritch School of Medicine. Program Director, Division of Pulmonary and Critical Care Medicine, Hines Jr. Veterans Affairs Hospital, Hines, IL.
- **Barry Make, MD** — Director of Pulmonary Rehabilitation, National Jewish Center for Immunology & Respiratory Medicine. Associate Professor of Medicine, University of Colorado School of Medicine, Denver, CO.
- **Dean Hess, MEd, RRT** — Assistant Director of Research, York Hospital. Program Director, York College of Pennsylvania, School of Respiratory Therapy, York, PA.
- **Richard D. Branson, RRT** — Clinical Instructor of Surgery, Division of Trauma and Critical Care, University of Cincinnati Medical Center, Cincinnati, OH.

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